

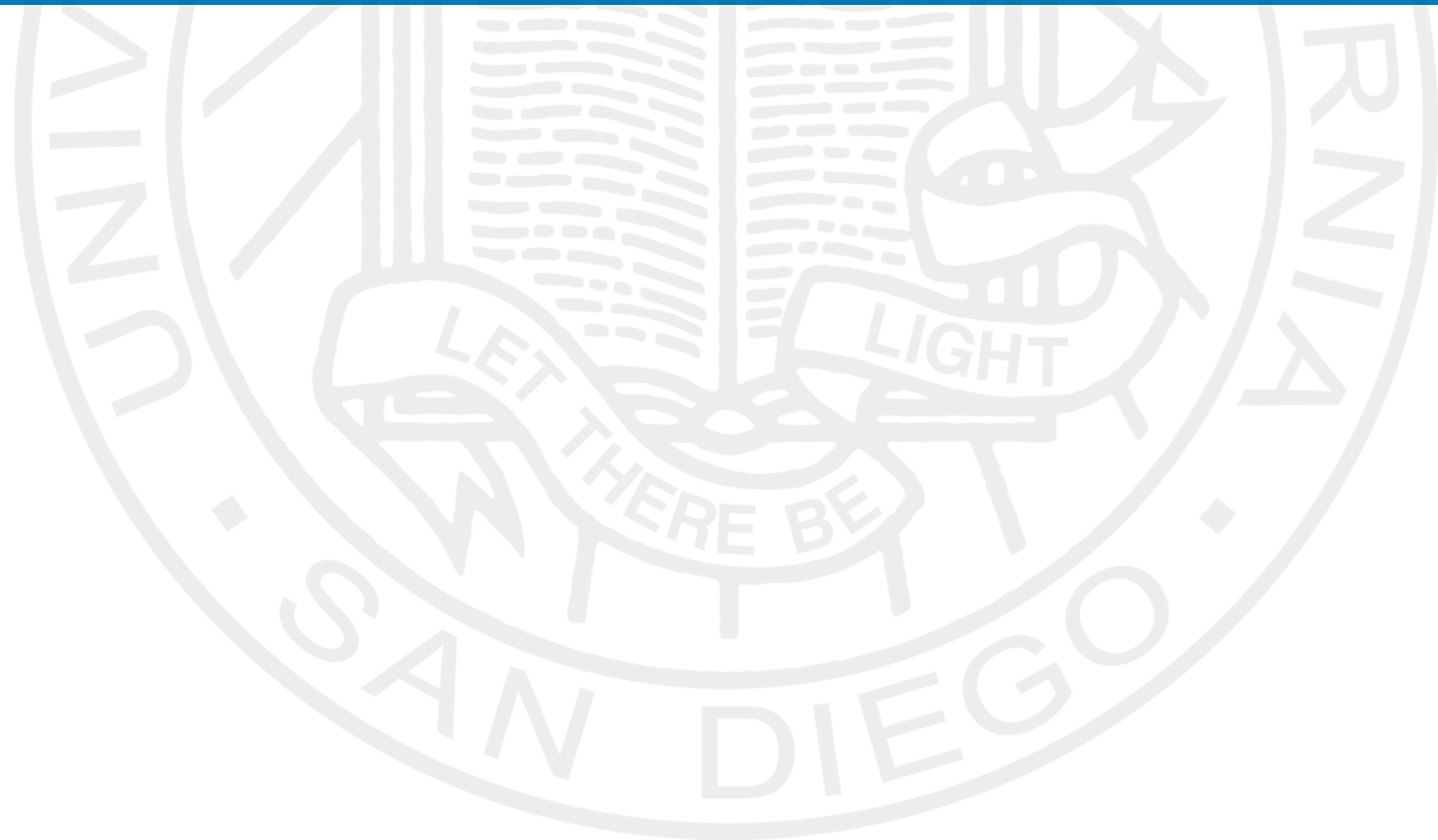
Personalizing Patient Care Via Daily Adaptive Radiation Therapy

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Assistant Professor
Radiation Medicine & Applied Sciences

UC San Diego Health

RETHINKING MEDICAL PHYSICS



Disclosures

- I have received honoraria and speaker fees from Varian
- I have a current Lab Services Agreement with Varian
- I am a clinical investigator on a Varian-sponsored clinical trial

Moore's Cancer Center at UC San Diego

- 2 TrueBeam[®] systems
- Halcyon[®] system
- Ethos[™] therapy



- Treat ~180 patients/day
- 2500 new patients/year

Clinical Ethos Team at UCSD



Jyoti Mayadev,
MD



Brent Rose,
MD



Chika Nwachukwu,
MD, PhD



AJ Mundt,
MD



Dominique Rash,
MD



Xenia Ray,
PhD



Kelly Kisling,
PhD



Grace Kim,
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Casey Bojecho,
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Boyu Meng,
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Past & Present Research Team



Antonia Wuschner,
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Rupesh Ghimire,
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Mojtaba Moazzezi,
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Kevin Moore,
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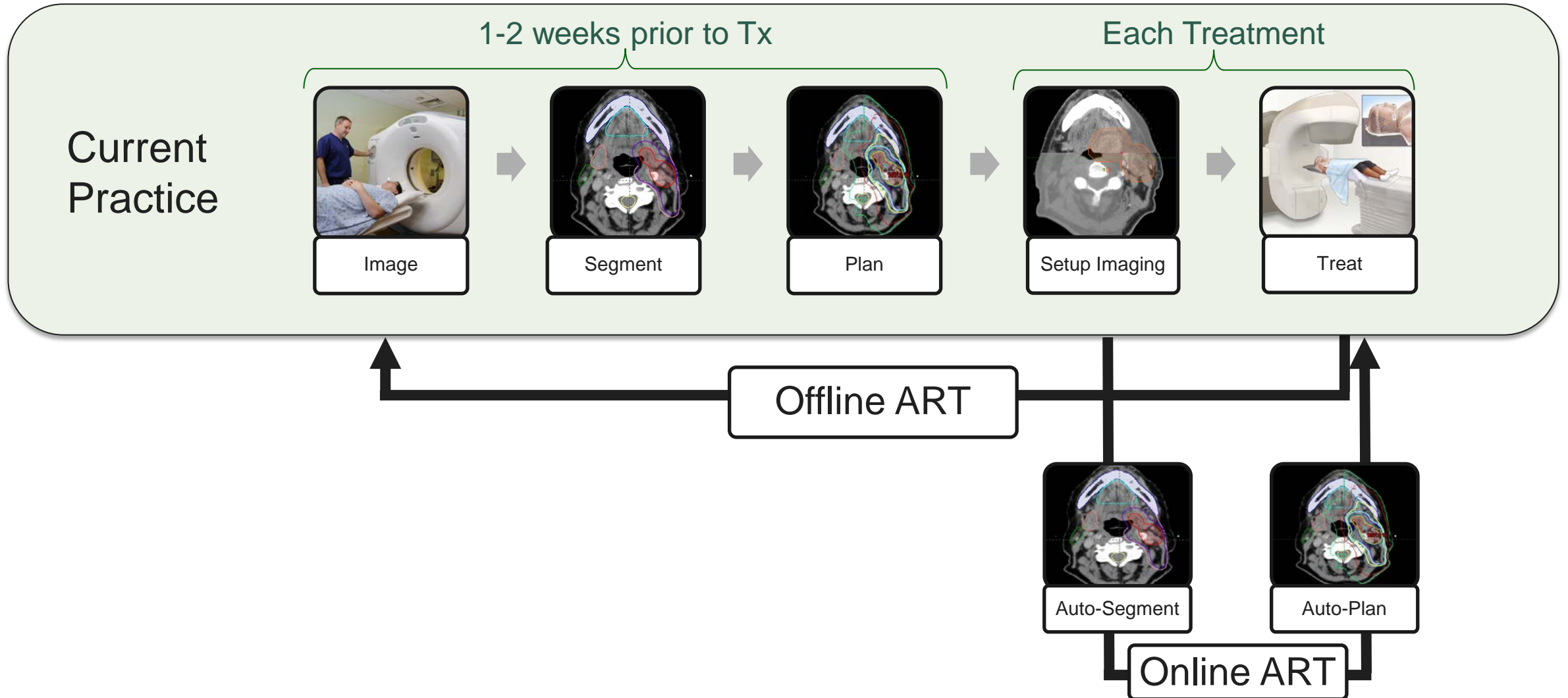
Kelly Kisling,
PhD

Outline

- Adaptive Radiotherapy Introduction
- Ethos Overview
- Common Questions with Answers
 - What sites do you treat, what sites do you adapt?
 - Who does what during the adaptive process?
 - How long does it take?
 - How do you pick who you will adapt?
 - Are you changing margins?

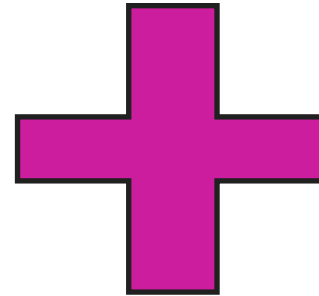
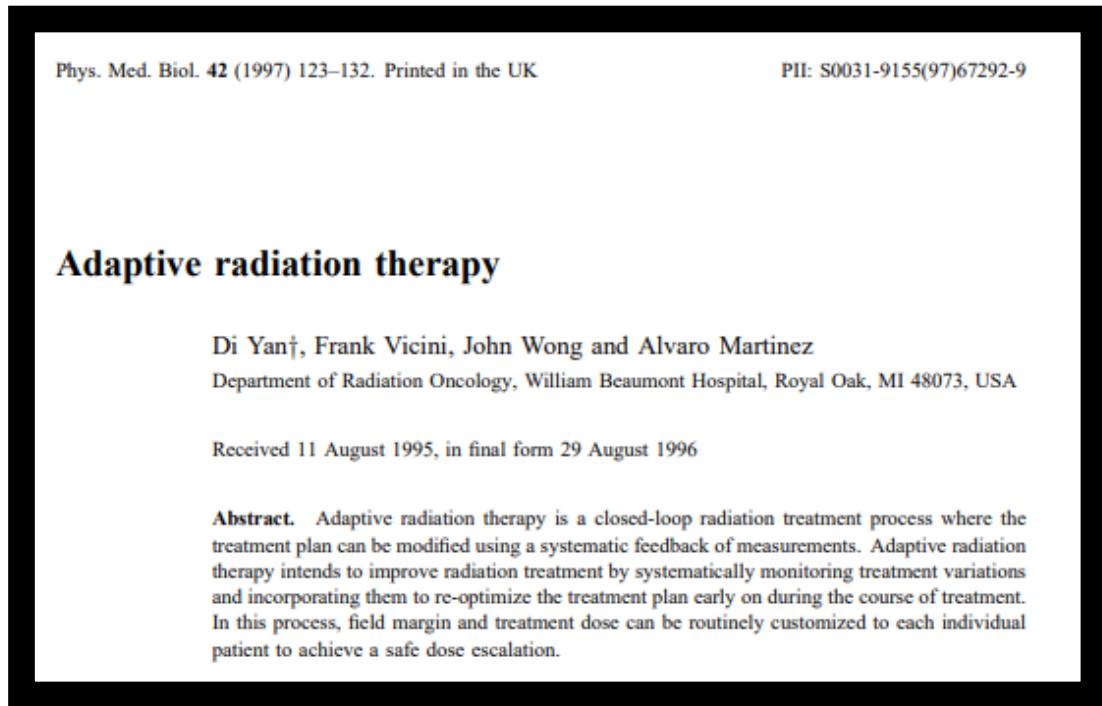
Introduction to ART

What is Adaptive Radiation Therapy?

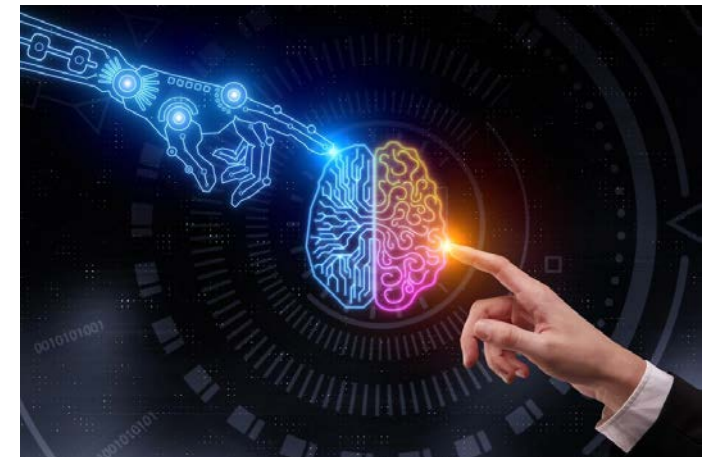
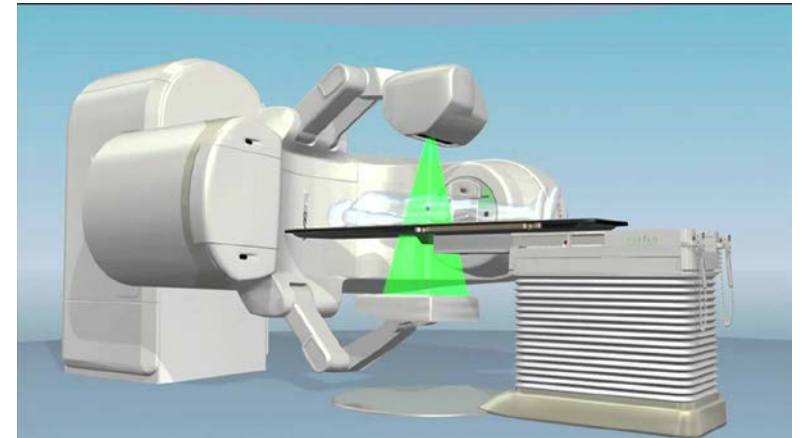


Evolution of Adaptive RT

First published reference from 1997

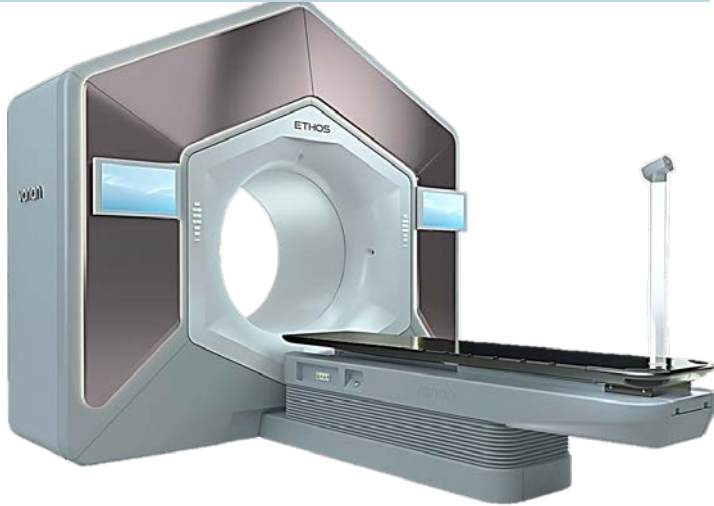


30 years of hardware and software improvements

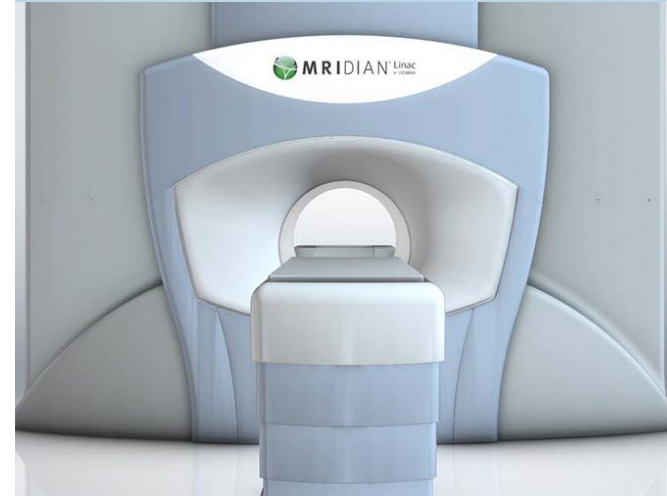


Commercial Solutions for Online Adaptive RT

Varian Ethos



ViewRay MRIdian



RefleXion X1 Scintix



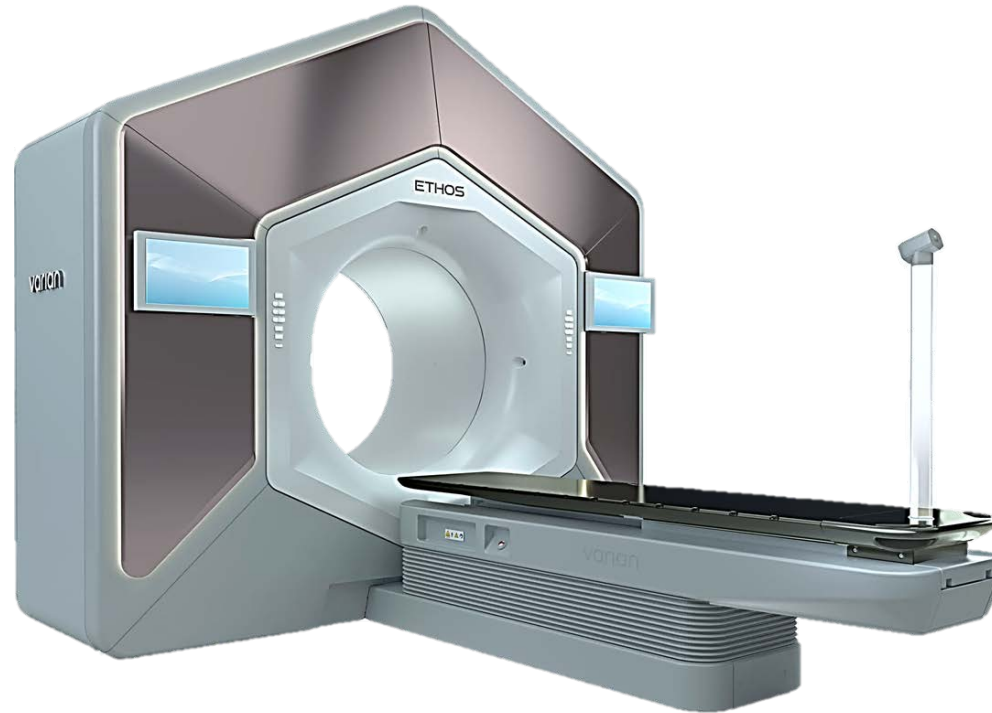
Elekta Unity MR-Linac



Introduction to the Varian Ethos™

General

- Single Energy: 6 MV FFF
- 28x28 Field Size
 - Extended fields can be treated with 2 isos
- Dual-layered MLC
 - Effective 0.5cm resolution at iso
- Closed beam model
 - Acuros
- Separate TPS outside of ARIA
- **Can treat adaptive and non-adaptive patients**



Adaptive

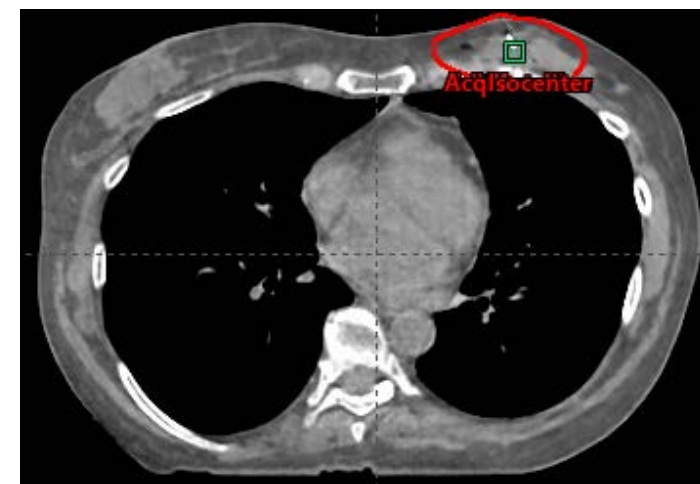
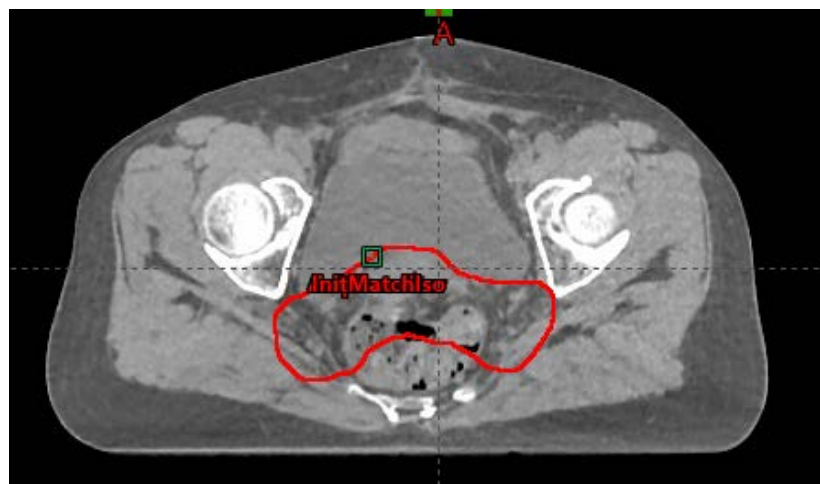
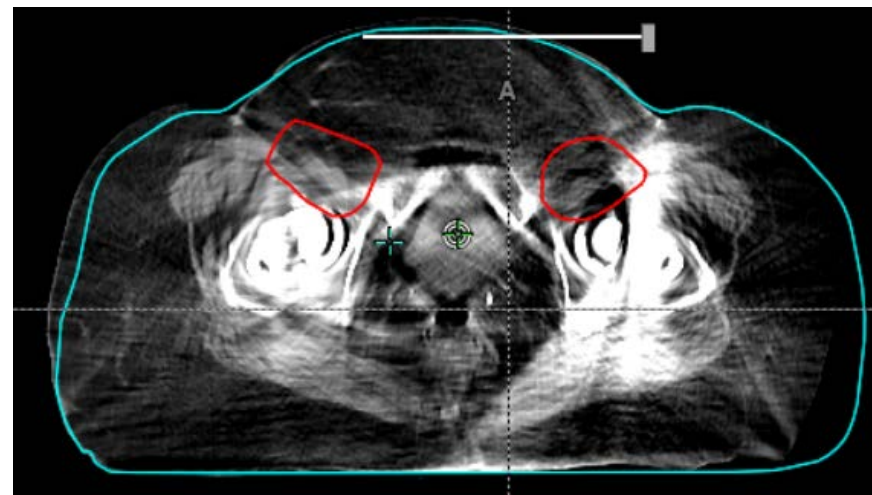
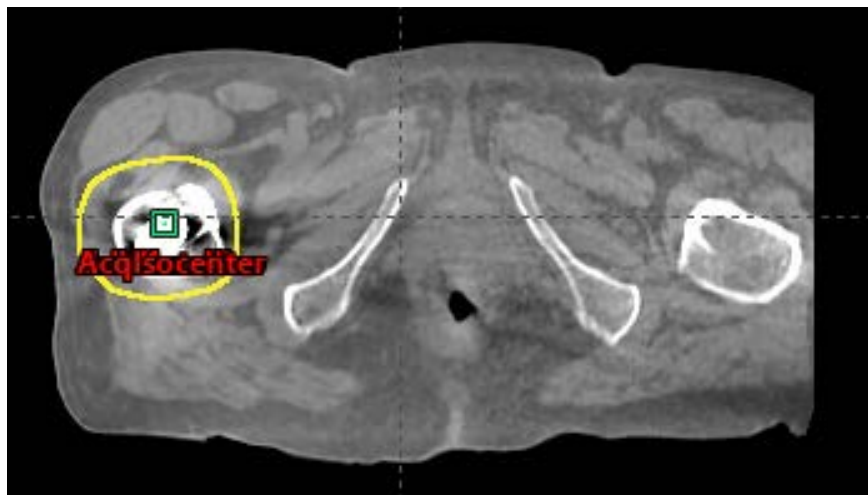
- Adapts on kV-CBCT images
 - Fast & familiar
 - HU accuracy with Hypersight™
- Stream-lined replanning
 - Use pre-plan's 'recipe'
 - Intelligent optimization engine (IOE) guides opt
- ART patients repeat adaptive process every fx

HyperSight Imaging Panel

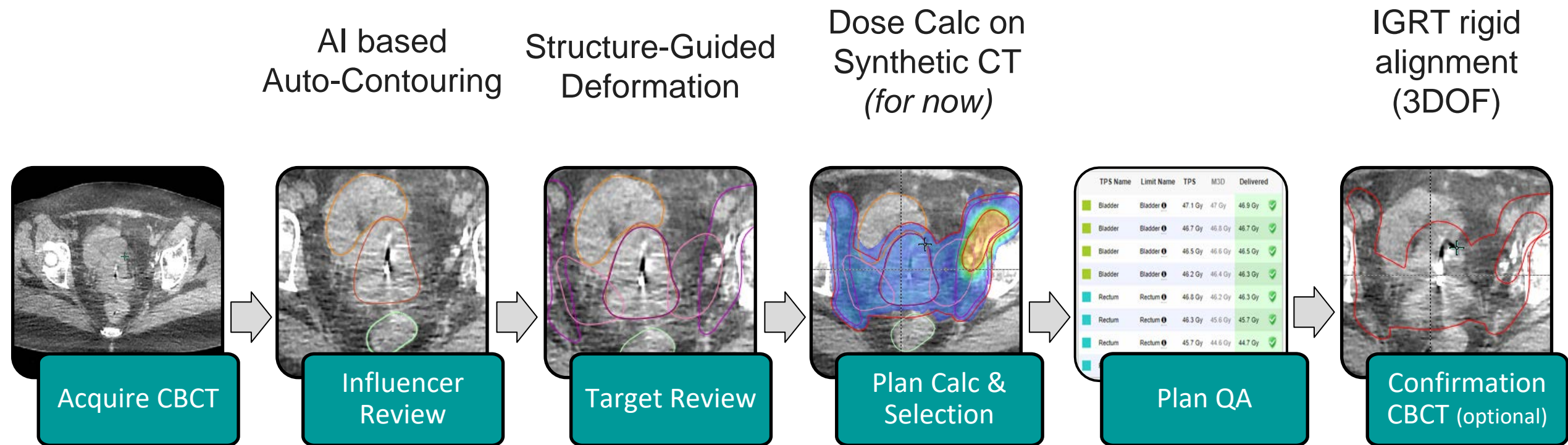
- Installed on both Ethos and Halcyon
- Advantages:
 - 6 second acquisition
 - Can CBCT in 1 Breath-hold
 - May be useful for treating more patients with BH
 - Extended lateral FOV (70cm)
 - Metal Artifact Reduction (MAR) option
 - **Potential to calibrate CBCT pixel intensities to HU and use for dose calculation**



More Hypersight Images? Yes Please



Daily Adaptive Process with Ethos



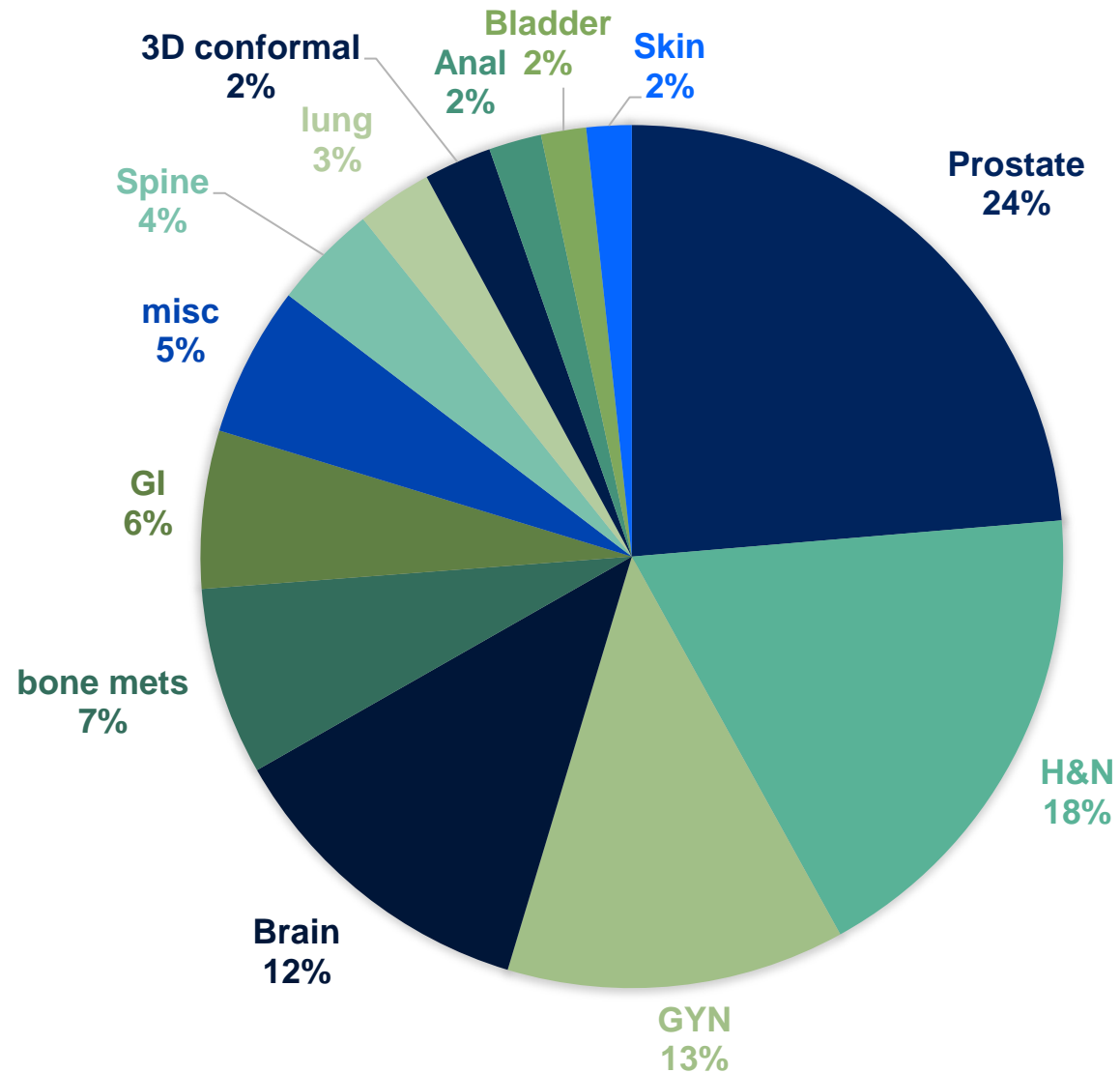
Ethos at UCSD

UCSD Ethos Experience

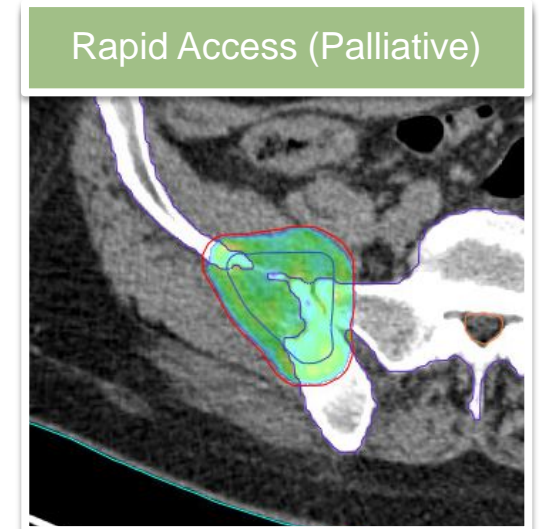
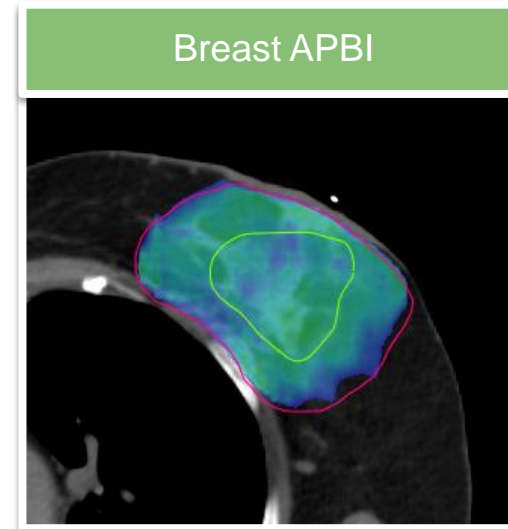
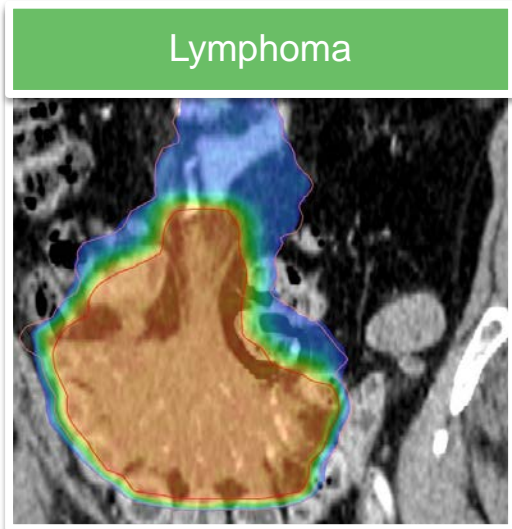
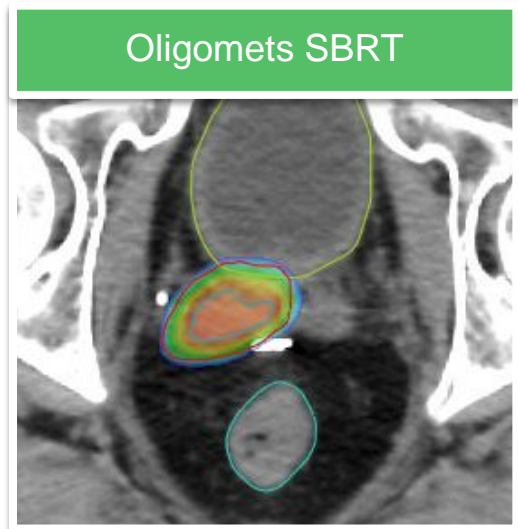
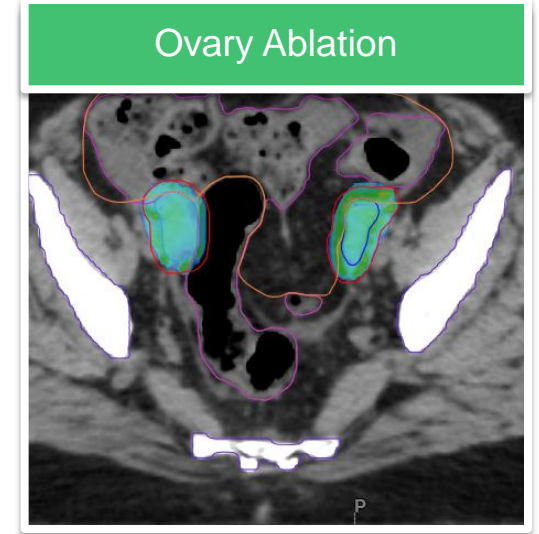
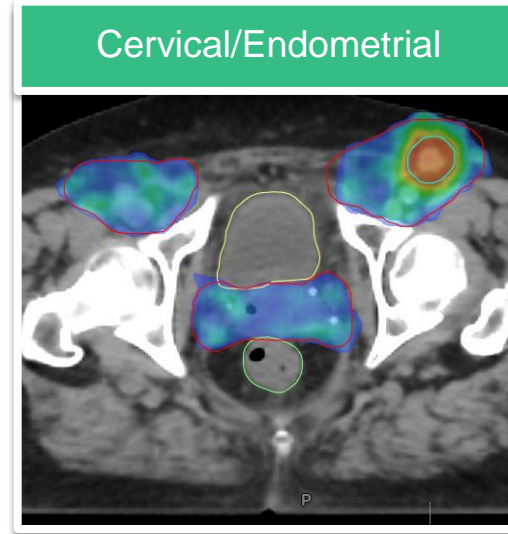
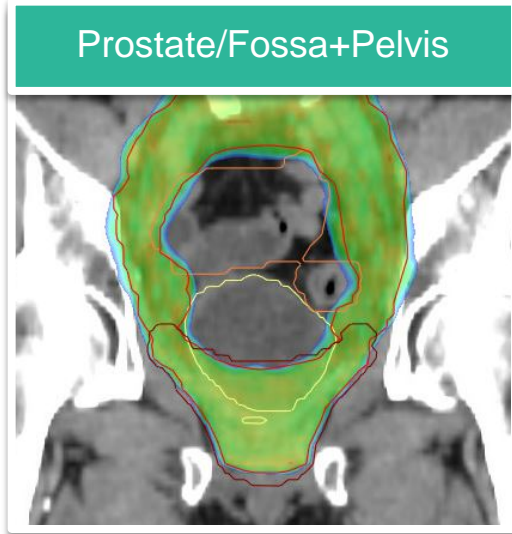
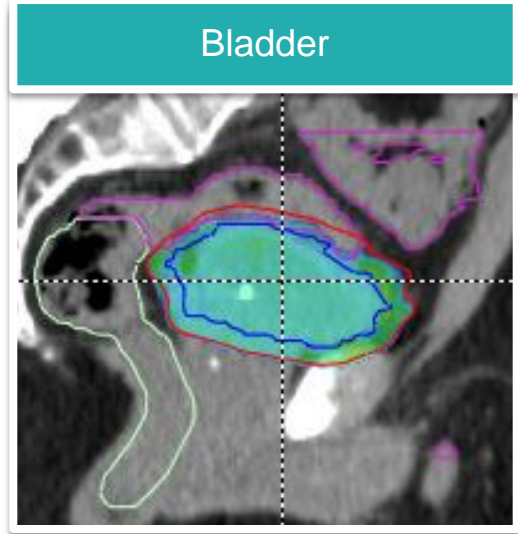


- Went live September 2021
- Have treated 500+ non-adaptive patients and 50+ adaptive patients
- 40-60 total TXs per day
- 1-4 ART TXs per day
- Time slots:
 - Non-Adaptive: 10 mins
 - Adaptive: 30 mins

IGRT & ART Treatment Sites on Ethos

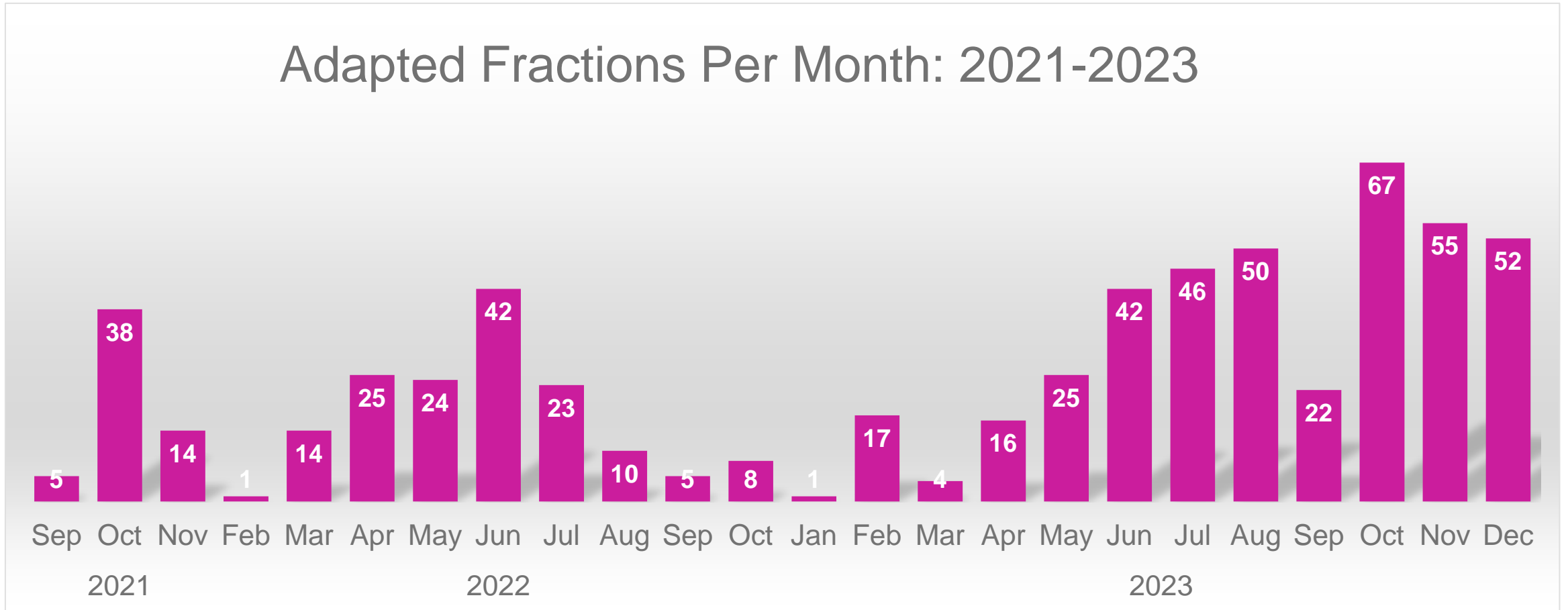


Adapted Treatment Sites at UCSD



Adaptive Treatments

Adapted Fractions Per Month: 2021-2023



Adaptive Roles at the Machine

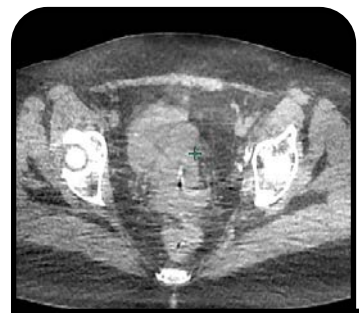
Therapist

Co-piloting

Physicist

MD

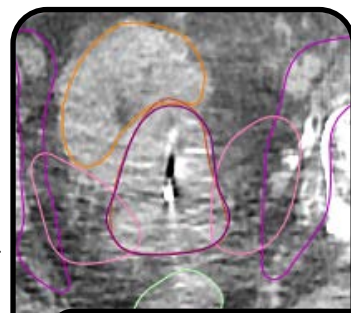
Fx1*



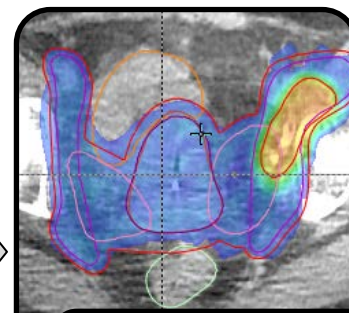
Acquire CBCT



Influencer Review



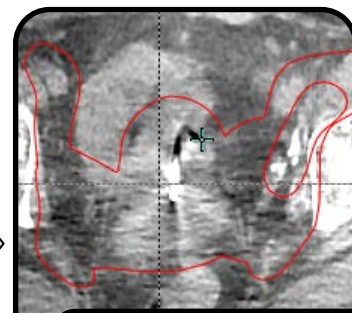
Target Review



Plan Calc & Selection

TPS Name	Limit Name	TPS	MDD	Delivered
Bladder	Bladder 1	47.1 Gy	47 Gy	46.9 Gy ✓
Bladder	Bladder 1	46.7 Gy	46.8 Gy	46.7 Gy ✓
Bladder	Bladder 1	46.5 Gy	46.6 Gy	46.5 Gy ✓
Bladder	Bladder 1	46.2 Gy	46.4 Gy	46.3 Gy ✓
Rectum	Rectum 1	46.8 Gy	46.2 Gy	46.3 Gy ✓
Rectum	Rectum 1	46.3 Gy	45.6 Gy	45.7 Gy ✓
Rectum	Rectum 1	45.7 Gy	44.6 Gy	44.7 Gy ✓

Plan QA



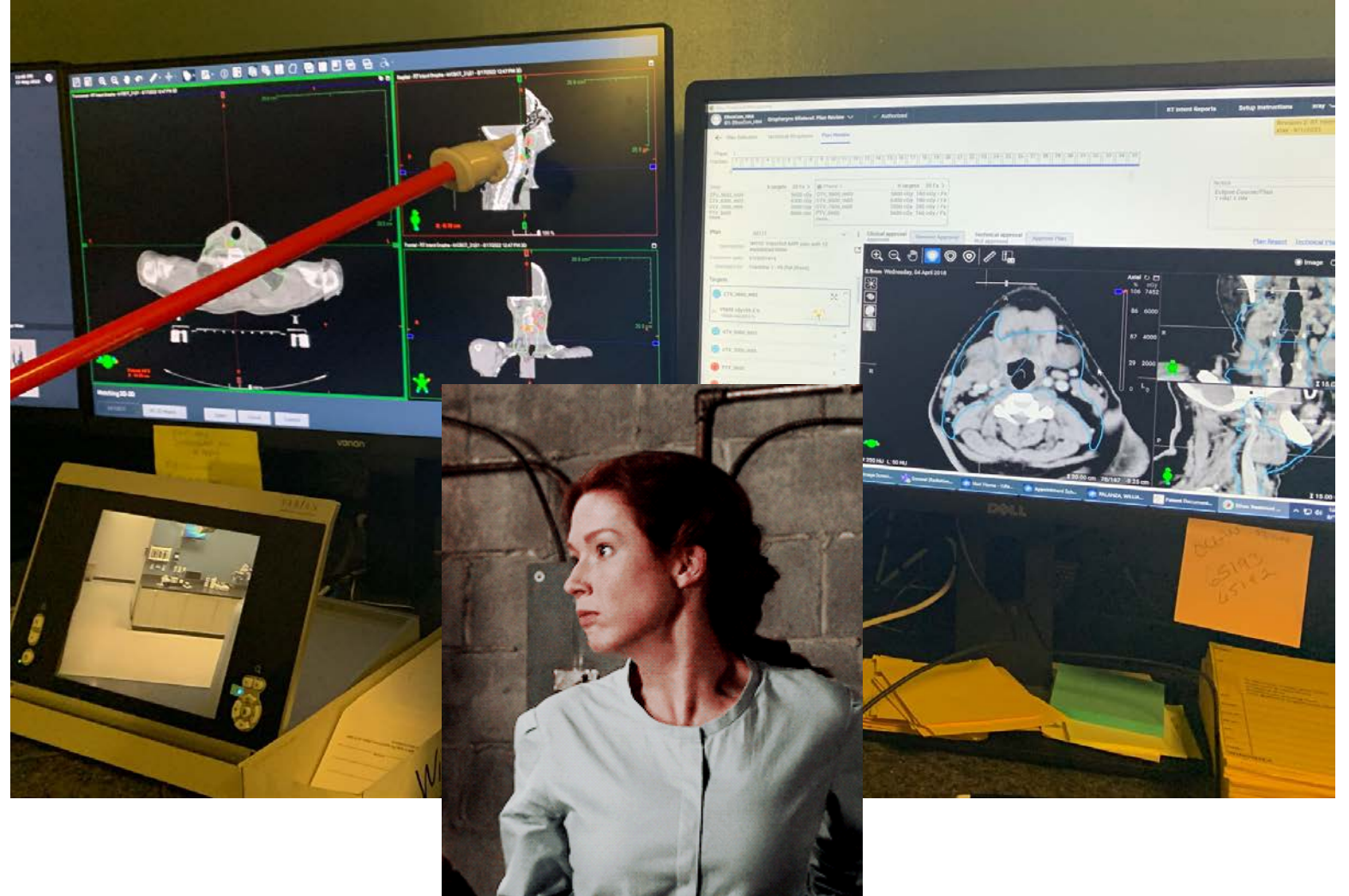
Confirmation CBCT (optional)

- Responsible
- - - Present
- · · Optional

Co-Pilot Role

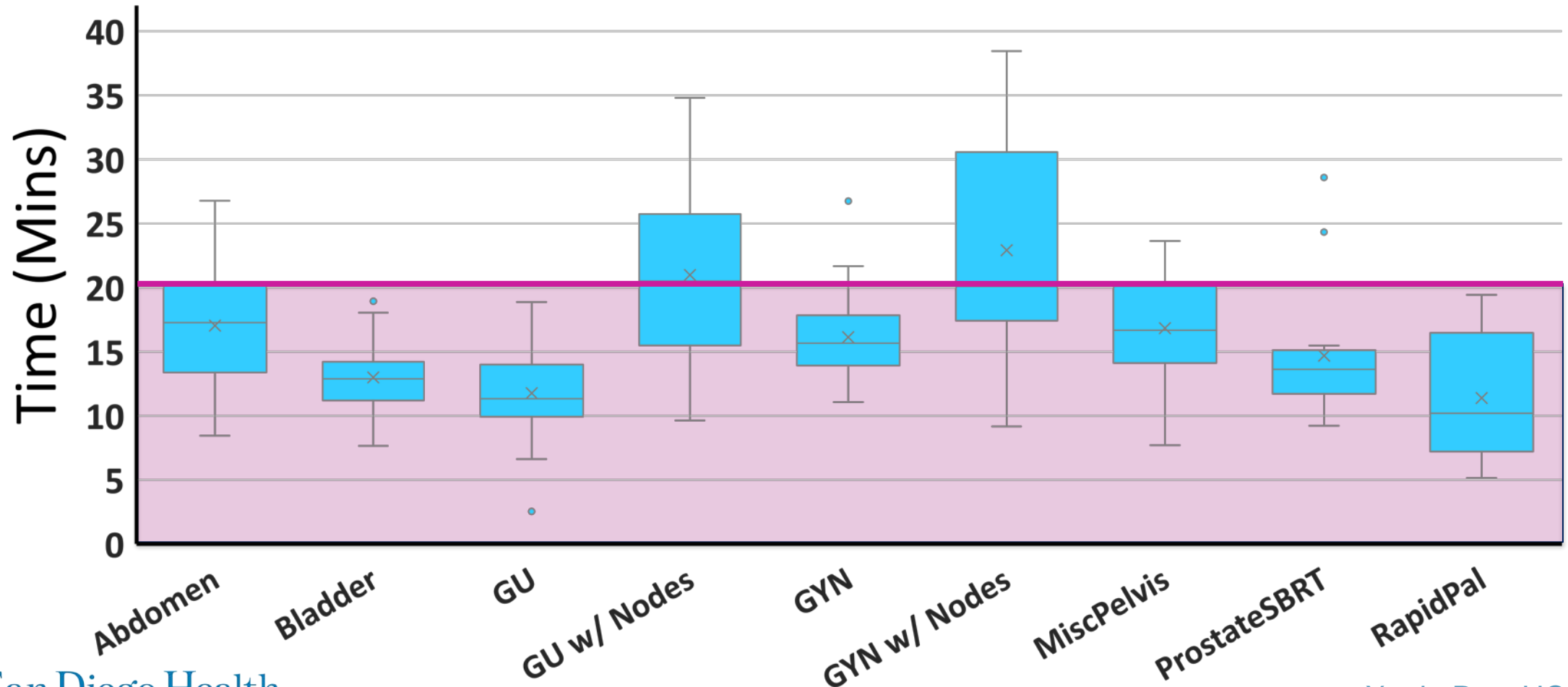
As adapter makes edits to the target, the copilot:

- Scrolls along on planning scan to show same image slice
- Reviews all edits compared to initial target
- Uses comically large pointer to highlight anything the adapter needs to edit further



Overall Time Required to Adapt

Majority of cases <20 mins from CBCT to Plan Approval
Volume and number of targets are biggest factors that impact the time required



Adaptive Patient Selection

- Hold spots from 9-11am daily
- Current max of 4 ART pats/day due to overall clinic load
- Has meant prioritizing the right patients for ART is critical
- Current Triage list:
 - ARTIA Trial Patients
 - Physician recommended patients
 - Breast APBI Pilot
 - GU w/ nodes



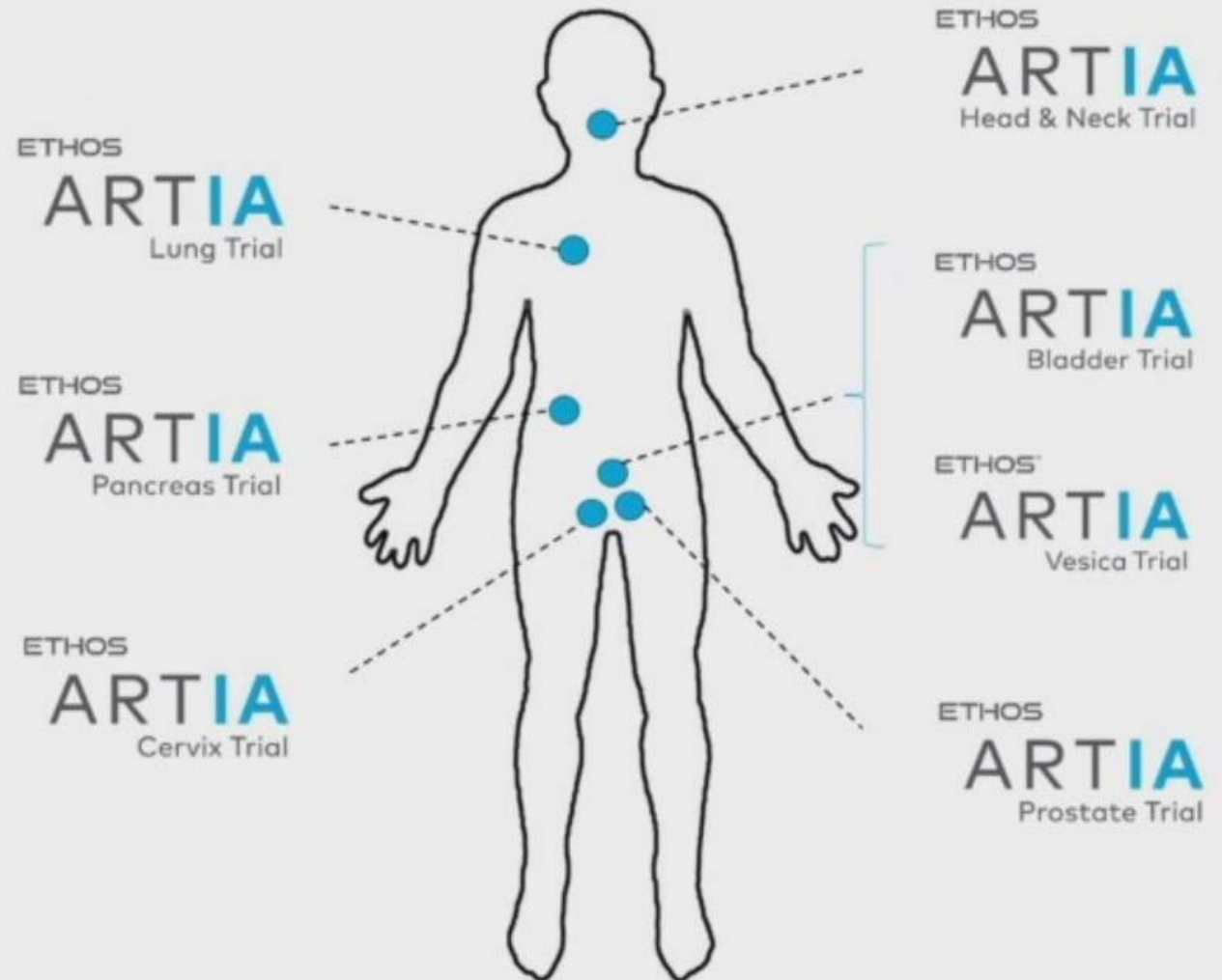
ARTIA Trials

Clinical trials evaluating dosimetric changes and reductions in toxicity from daily ART with Ethos

UCSD is the lead site for ARTIA-Cervix

Lead Physician: Jyoti Mayadev
Lead Physicist: Xenia Ray

Varian Sponsored Ethos Adaptive Trials
Adaptive Radiation Therapy using an
Individualized Approach (ARTIA)

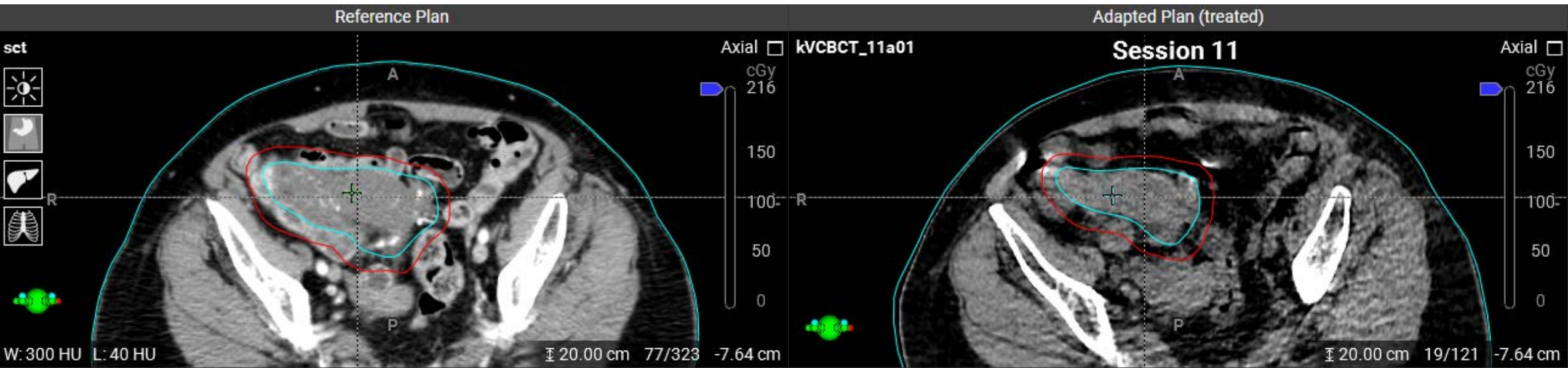


ARTIA-Cervix: Large Margin Reductions



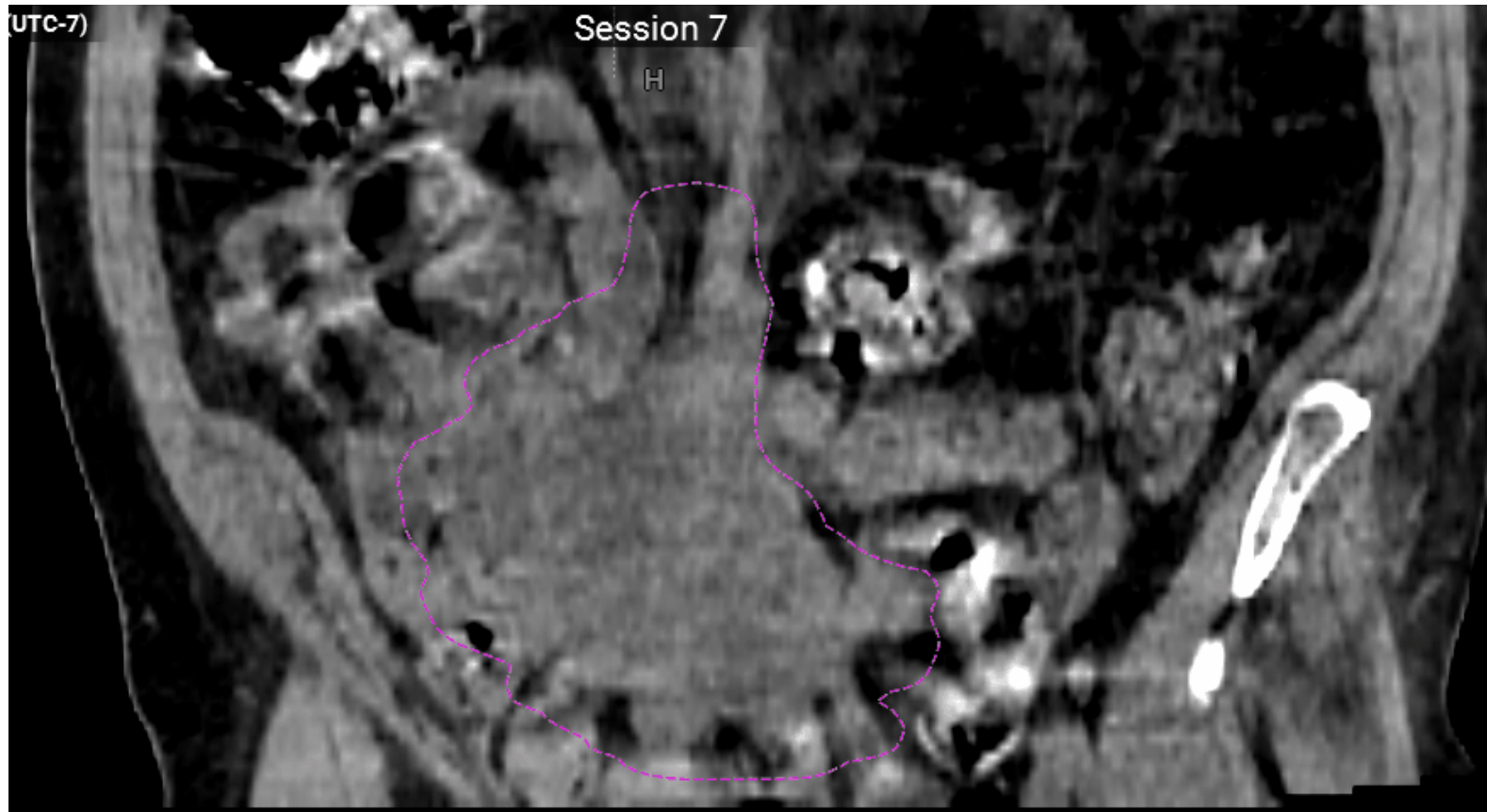
MD Request: Adapt Shrinking Targets

- 82 year old woman with stage IV diffuse large, B-cell lymphoma (DLBCL) with small bowel infiltration, now in partial response after R-miniCHOP



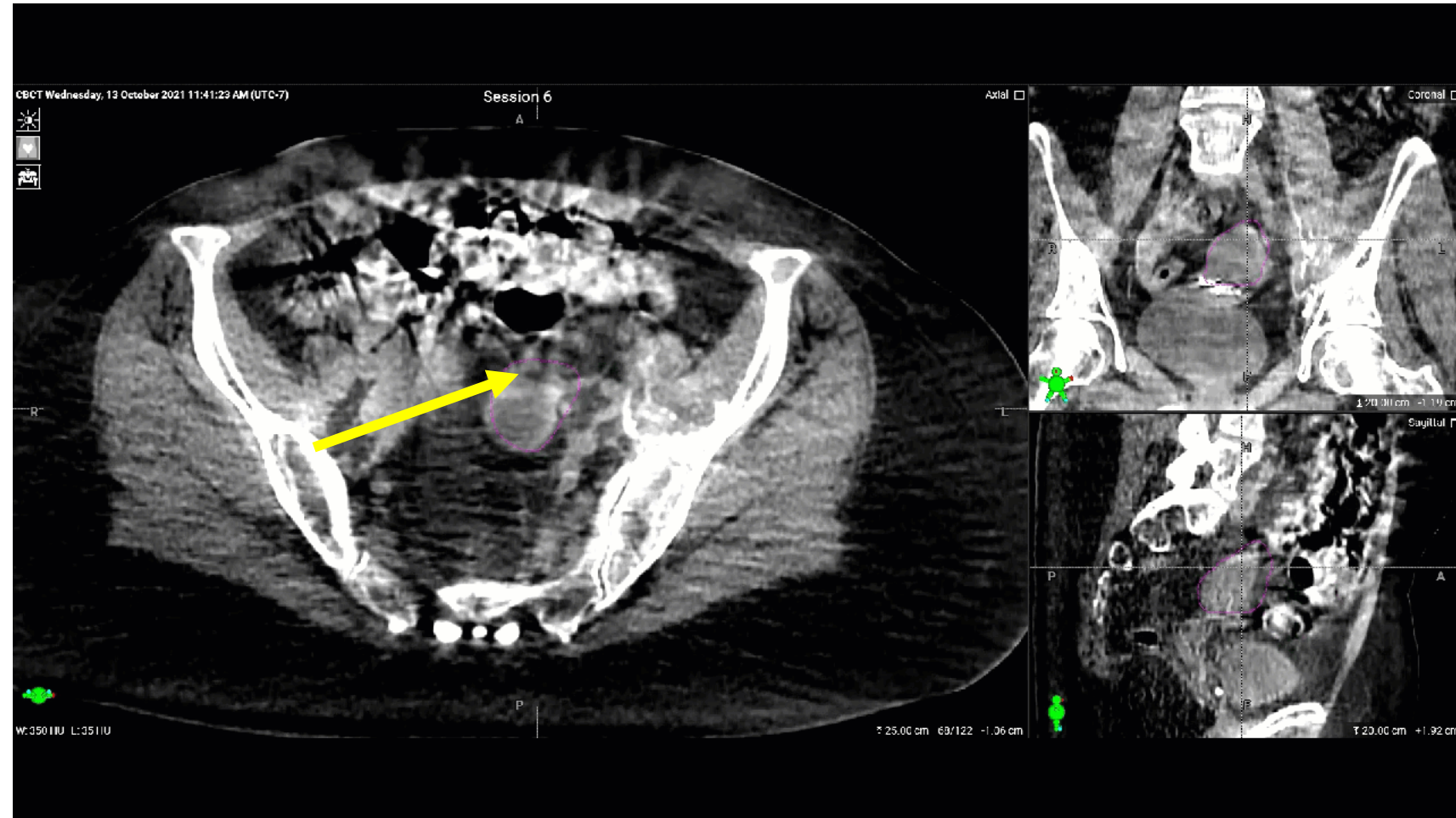
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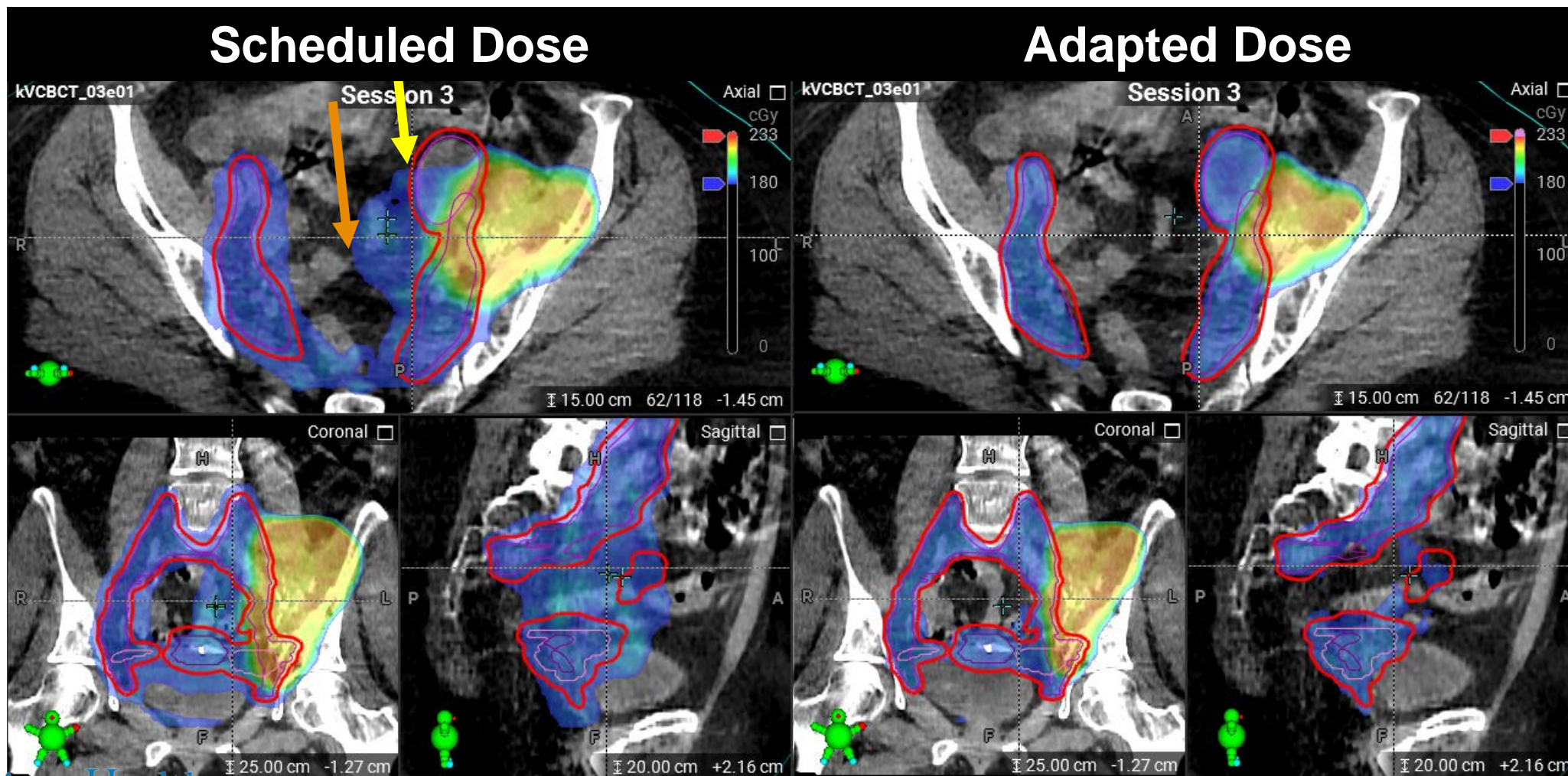
MD Request: Adapt for Mobile Targets

- Cervical Cancer Patient
- Patient also had a large ovary the MD wished to treat
- Without daily adaptation, this would have been highly suboptimal due to its substantial daily motion



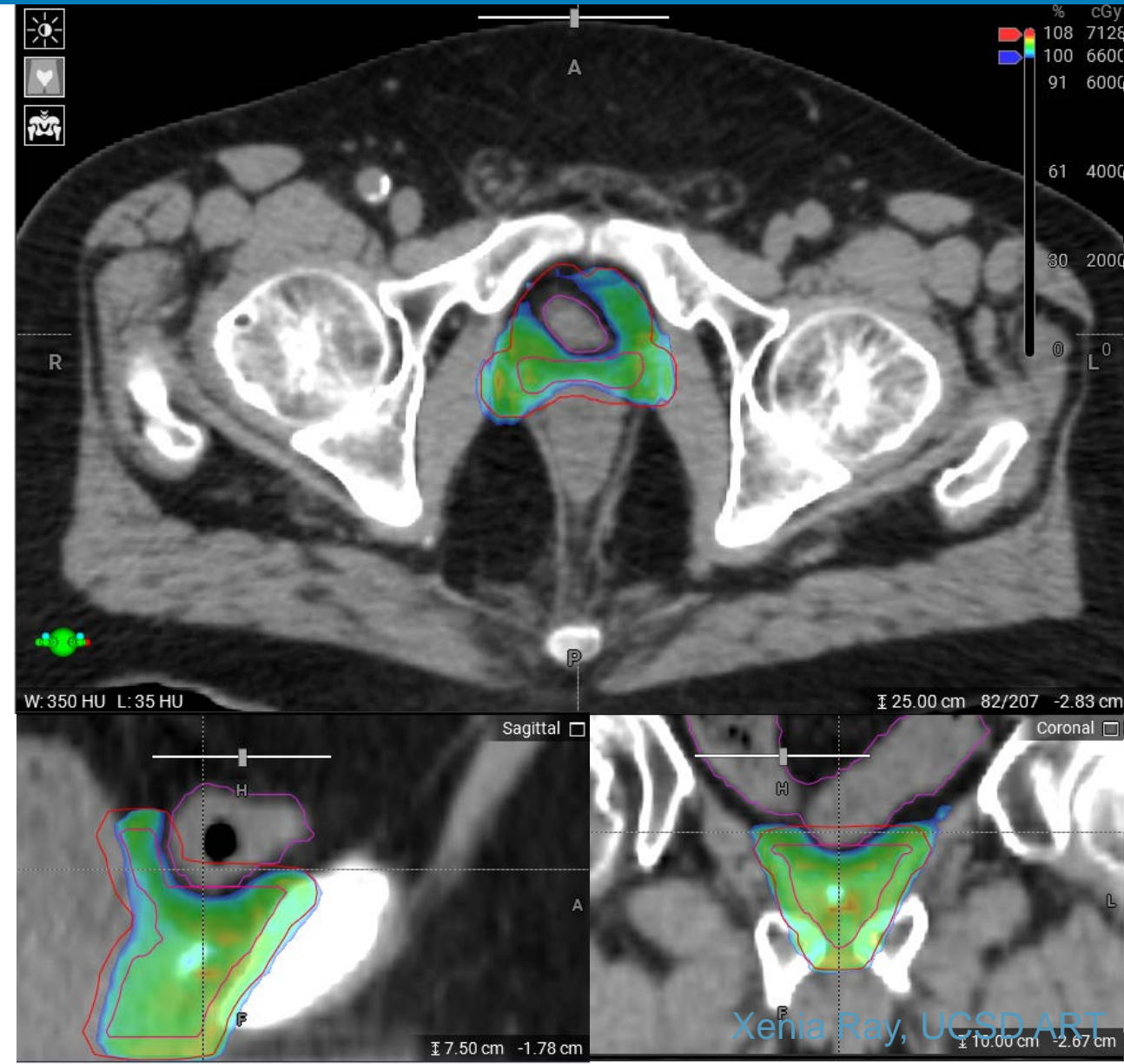
MD Request: Adapt for Mobile Targets

At many fractions, dose intended for the uterus would have been delivered to bowel instead



MD Request: Adapt for Mobile OARs

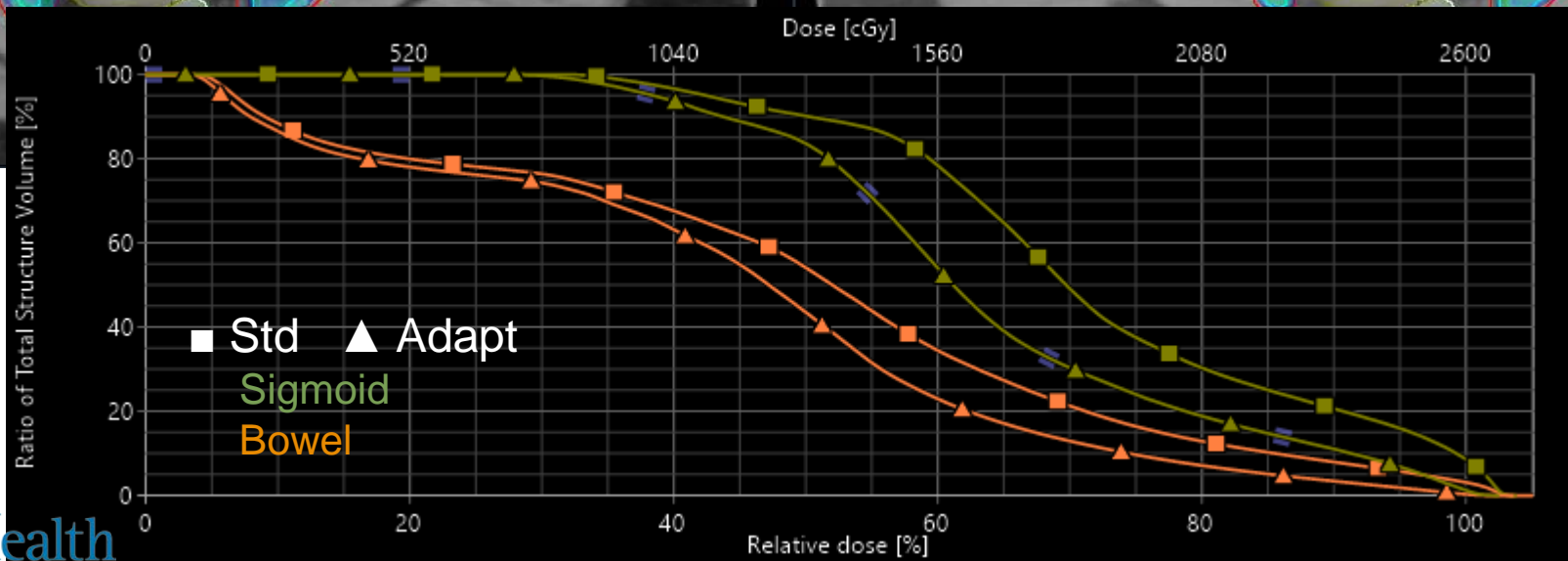
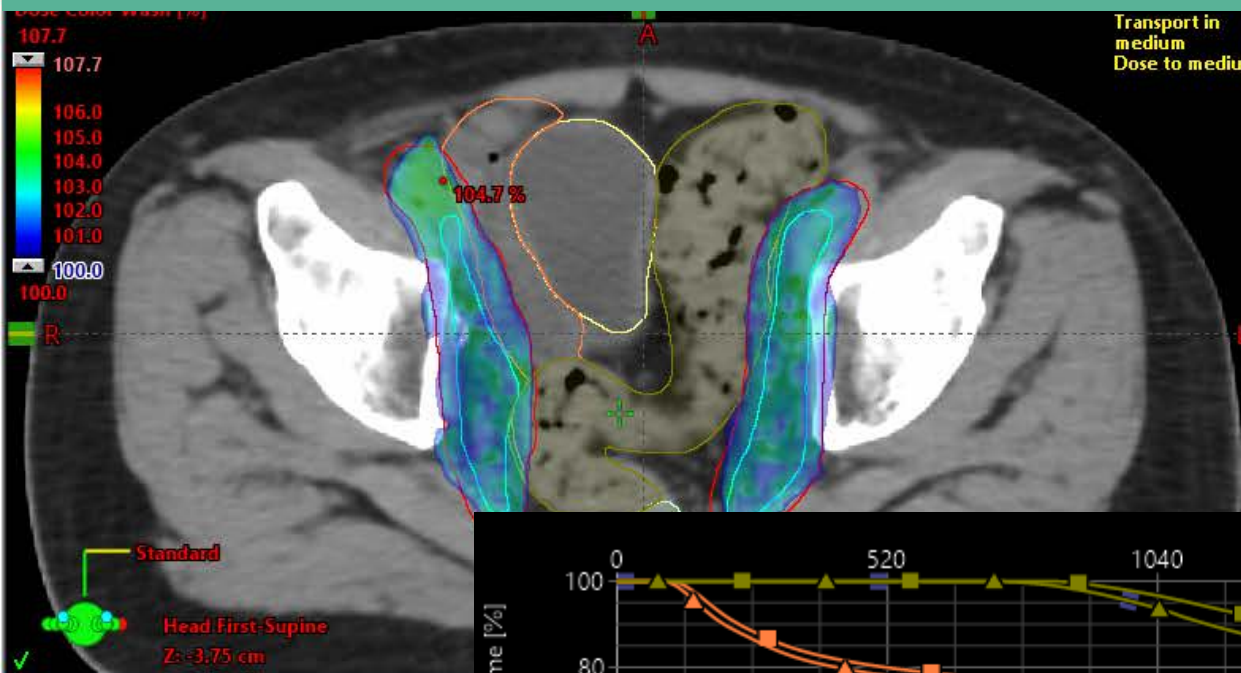
- 79 year old man with Stage IIIB prostate cancer
- Status-post Cystoprostatectomy
- As a result Sigmoid overlapped with the PTV
- RX: 66Gy in 33fx
 - Sigmoid limit < 60Gy
 - Small Bowel <54 GY
- Adapting allows us to check and modify plan daily for changes in loop positioning



MD Request: Adapt to Reduce Toxicity

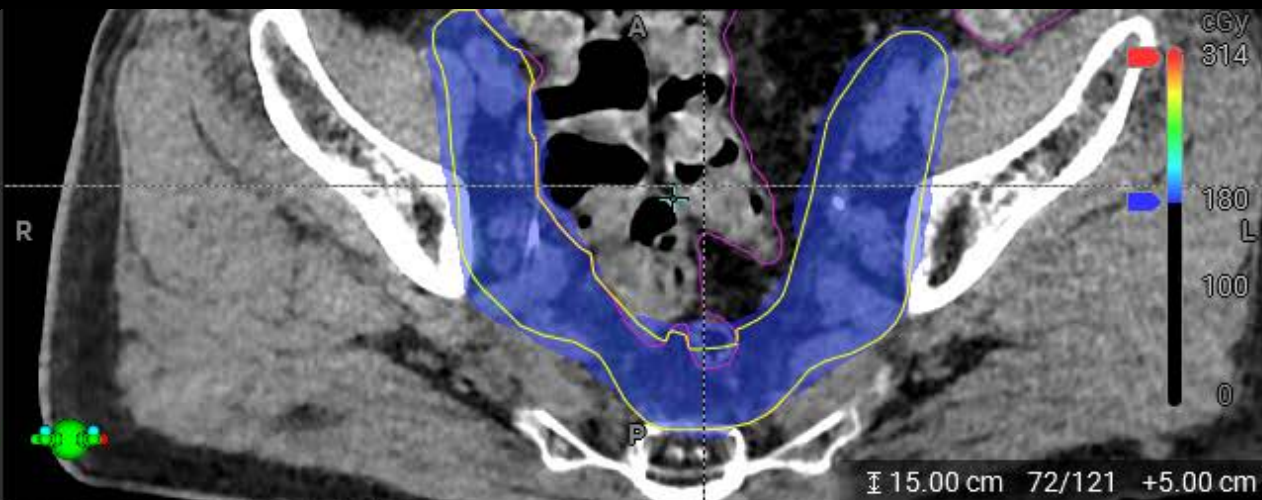
Non-Adaptive Backup Plan (5 mm)

Adaptive Plan (3mm & Bowel crop)

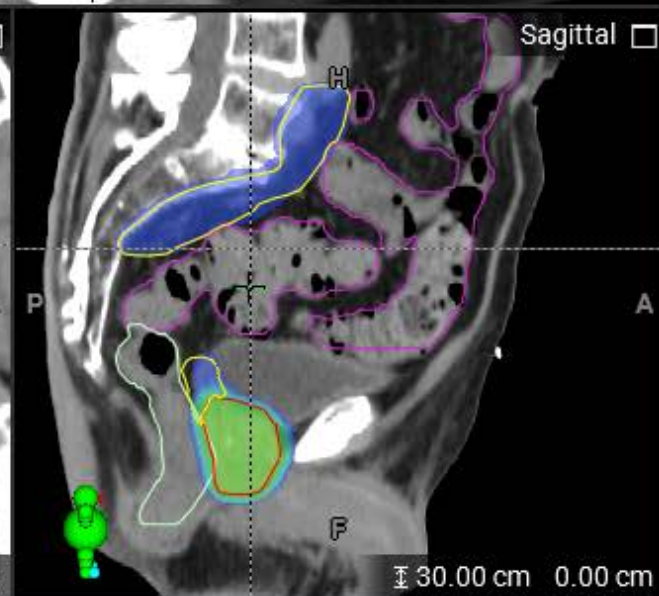
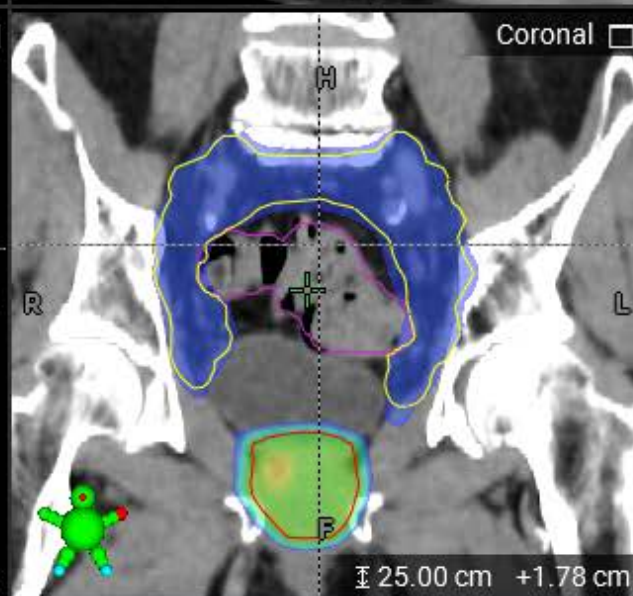
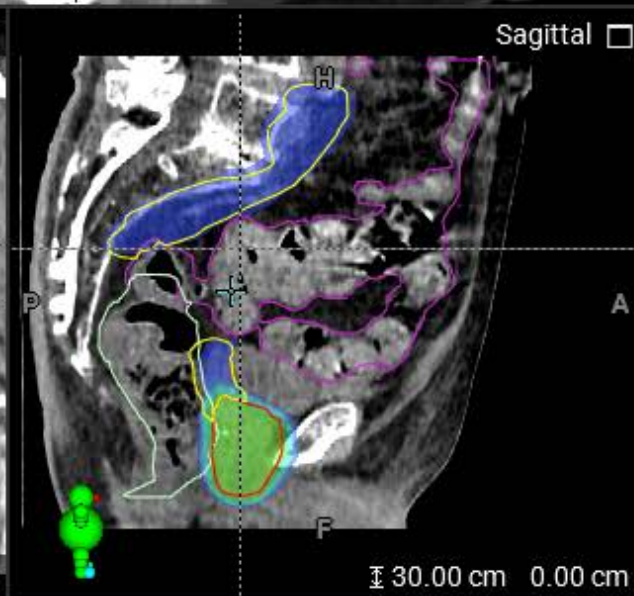
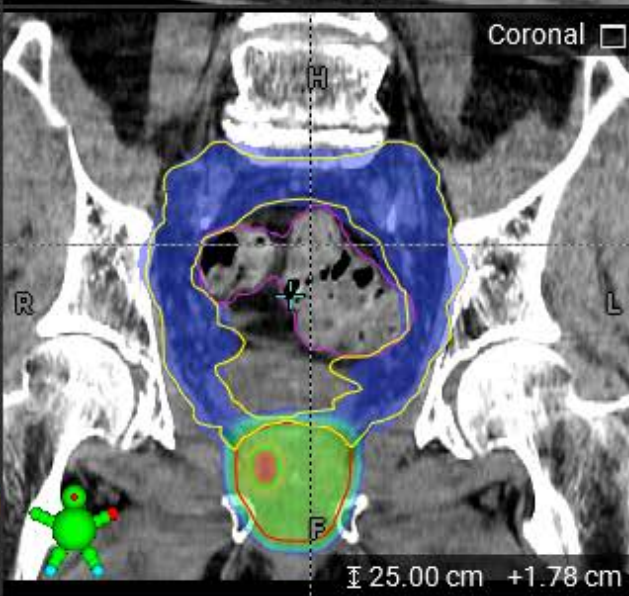
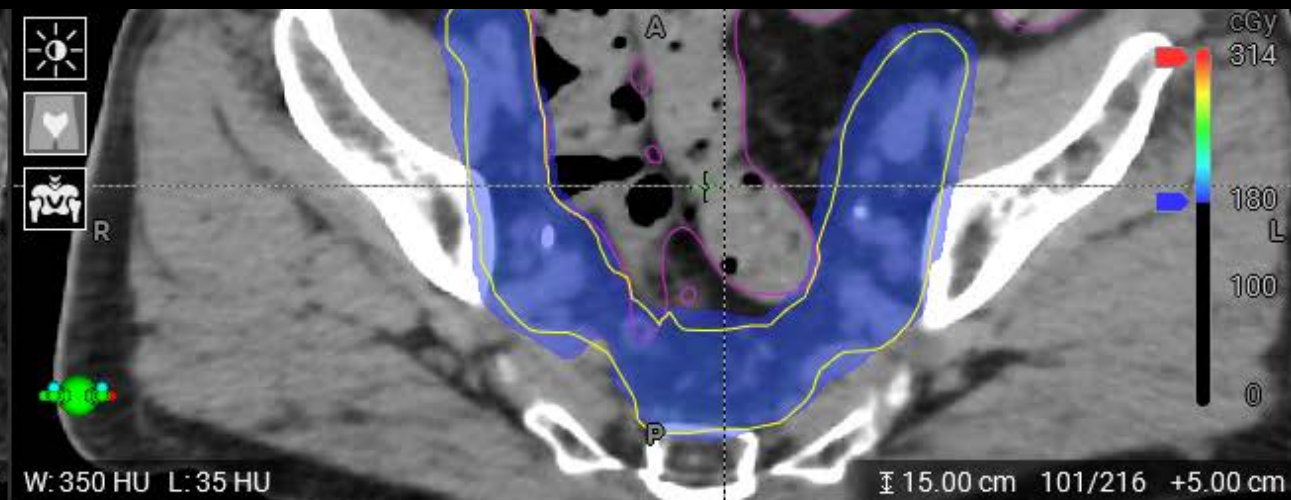


Adapt GU Cases with Nodes

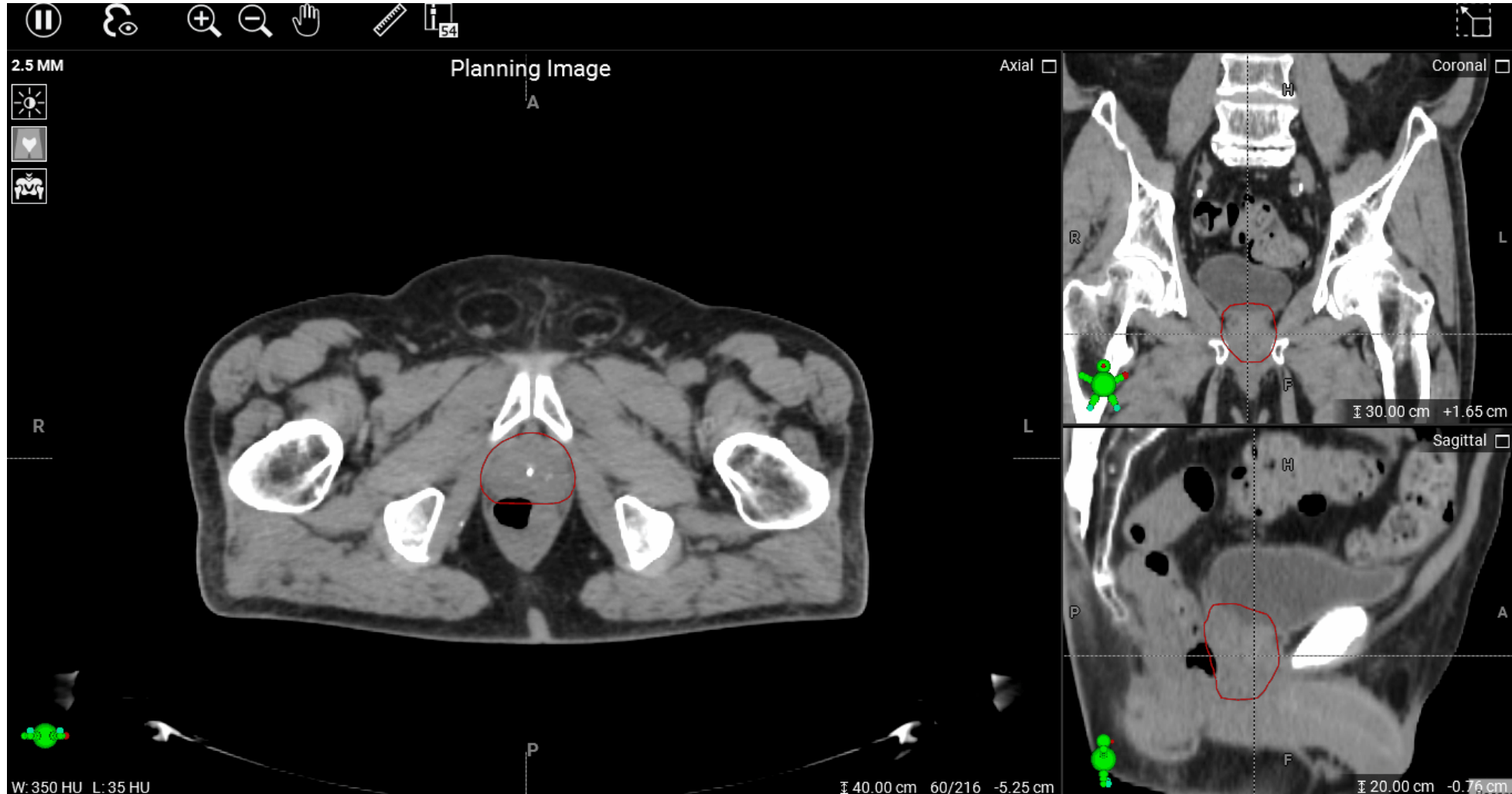
Adaptive Dose



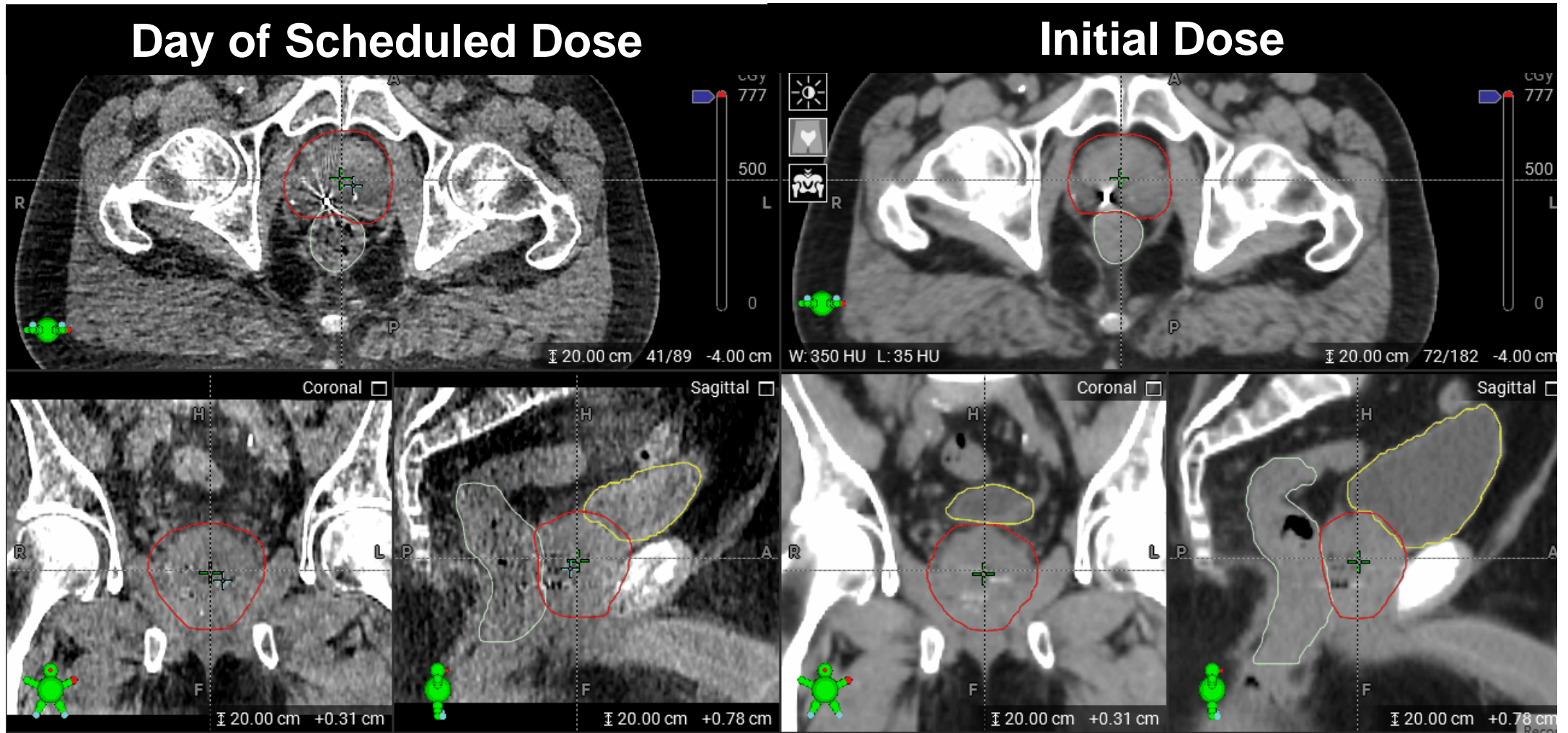
Initial Dose



Adapt GU Cases with Nodes



Clinical Experience: Prostate SBRT Patient

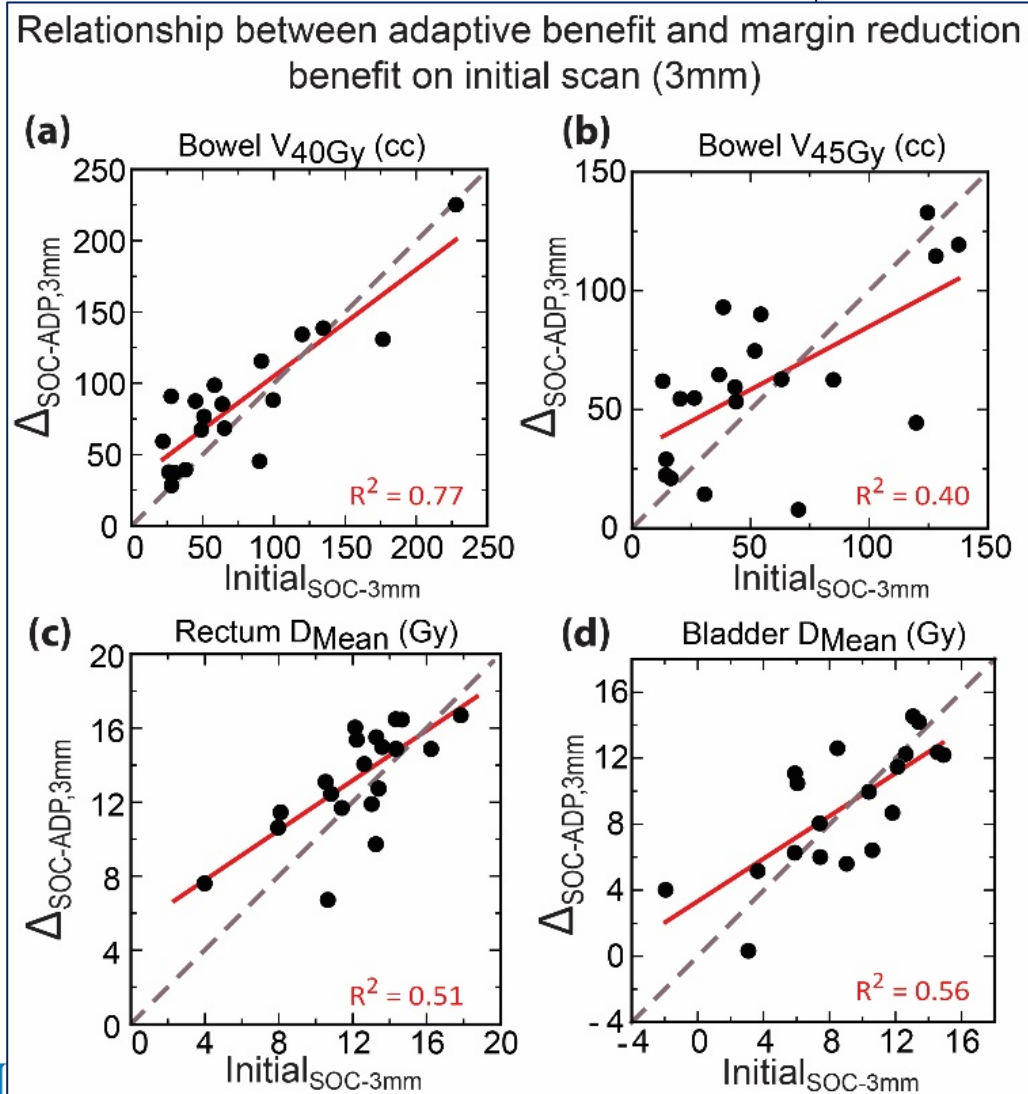


Research: Predicting highest benefit patients

IOP Publishing

Biomed. Phys. Eng. Express 9 (2023) 045030

<https://doi.org/10.1088/2057-1976/acdf62>



Biomedical Physics & Engineering Express

PAPER

Forecasting patient-specific dosimetric benefit from daily online adaptive radiotherapy for cervical cancer

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Keywords: adaptive radiotherapy, cervical cancer, CBCT-based adaptation, plan comparison, bowel toxicity, multivariate modeling

Supplementary material for this article is available [online](#)

- Evaluated 20 cervical cancer patients, treated 45Gy in 25 fx
- Found high correlation between predicted and true clinical bowel V40

Adaptive Margins

Systematic Margin Reductions

At UCSD, margin reduction has varied by case, physician preference, and our experience

Prostate

- SBRT: reduced from 3-5 mm to 2-4mm
- Conv: kept 4-7mm margins but cropped out Bowel+2mm

Prostate/Fossa+Pelvis

- Prostate/Fossa volume reduced from 4-7 to 3-5 mm margins
- Reduced nodal volume from 5 to 3mm

Post-Op Endometrial

- Reduced vagina PTV by not using an ITV and from 7mm to 5mm
- Nodal PTV reduced from 5 to 3mm

Cervical

- Uterus PTV reduced from 10mm to 5-10mm and no ITV
- Nodal PTV reduced 5mm to 3mm

Ovary Ablation

Using IMRT instead of 3D conformal and 5-7mm vs 20mm in backup plan

Bladder

8mm reduced to 5-7mm

Miscellaneous Pelvis

No reduction, used 3-5mm

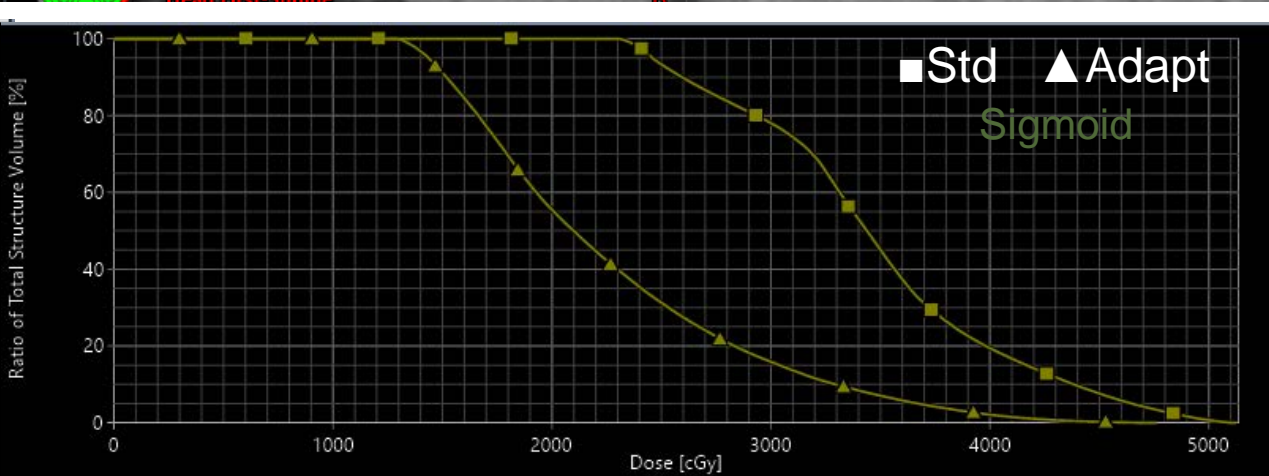
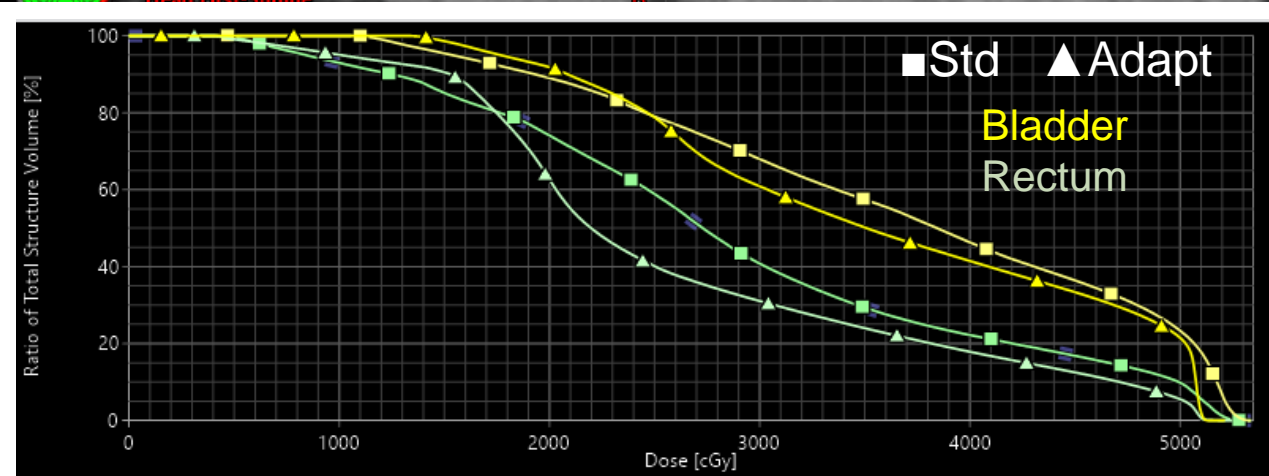
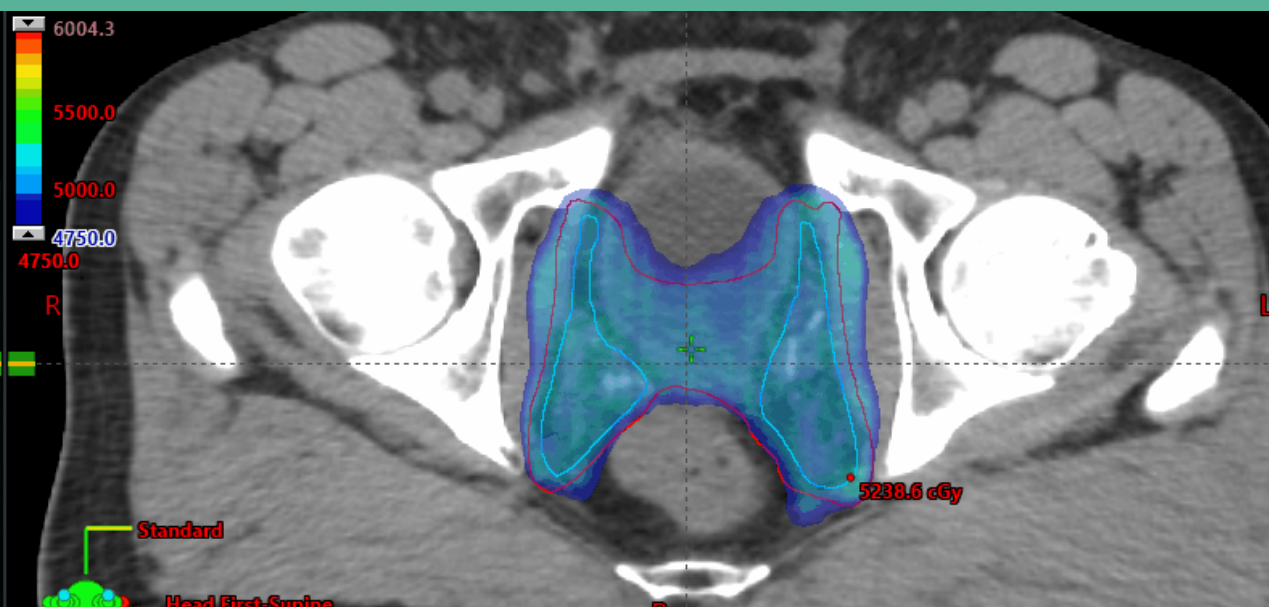
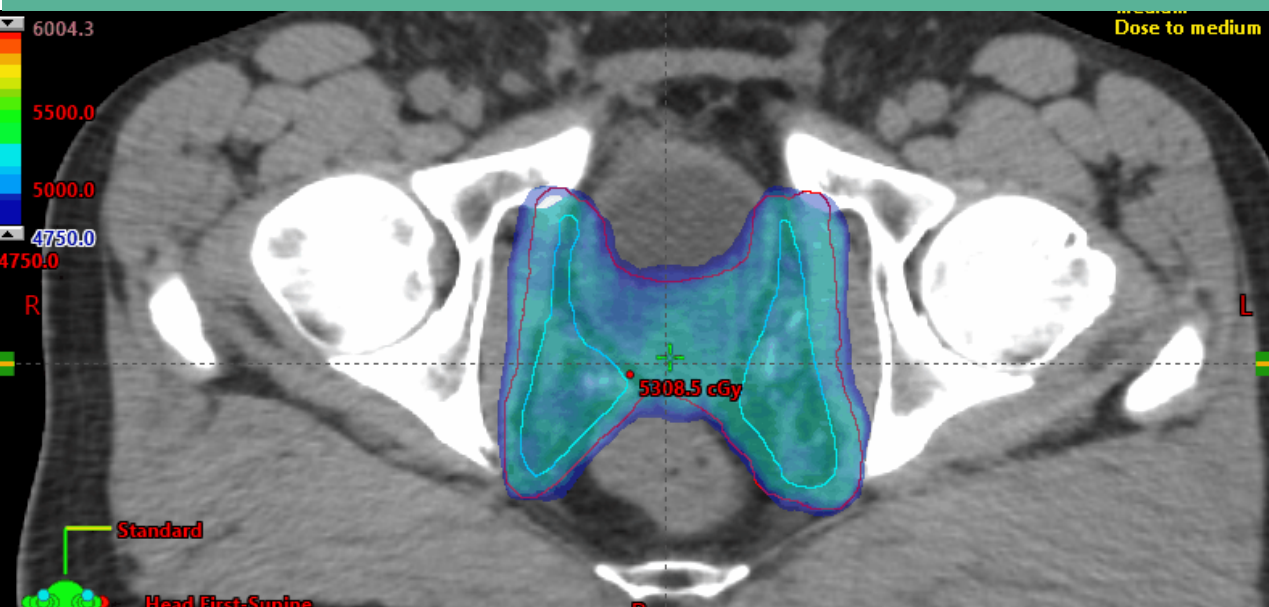
Rapid Palliative

Using IMRT with 5-7mm vs 3D conformal

Systematic Margin Reduction

Approved Backup Plan (5-7 mm)

Representative Adaptive Plan (3-5 mm)

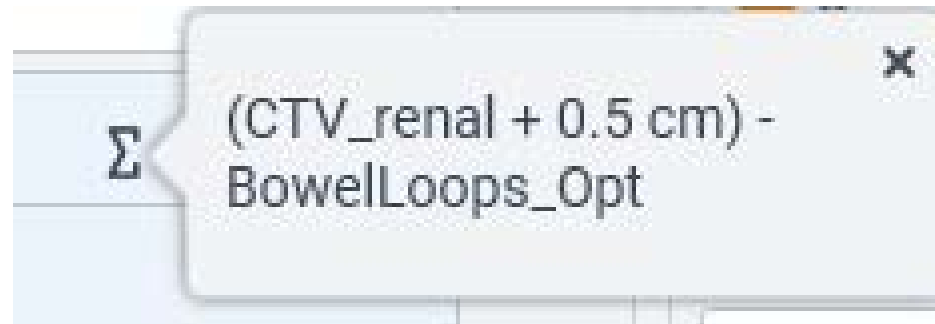


Adaptive Planning: Personalized Margins

- For Ethos adaptive patients, PTV targets margins are coded in

Meaning	Planning target volume				
Phase 1 Goal:	V100.0 %	\geq	95.0 %	P: R	● x Ri
Var:	V100.0 %	\geq	90.0 %		
Goal:	D0.03 cm3	\leq	102.0 %	P: R	● x Ri
Var:	D0.03 cm3	\leq	110.0 %		

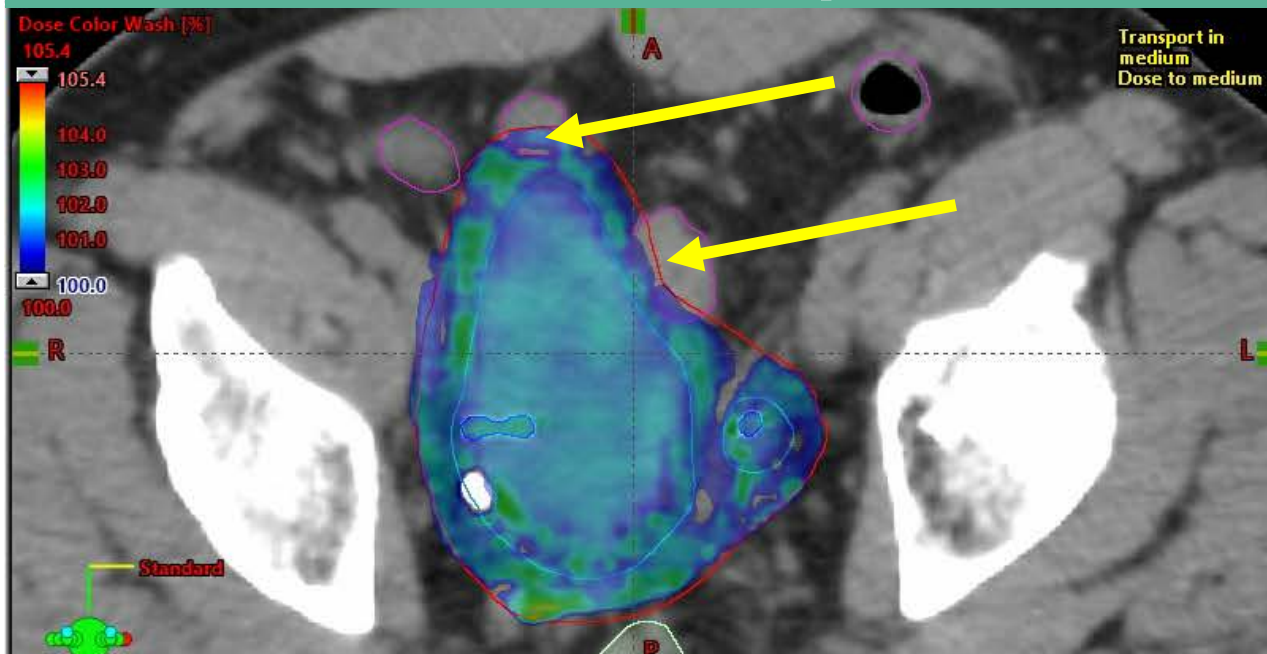
- For the daily re-optimized plans, margins can be tighter than standard because we will be verifying CTV each fx
- Additionally, if a specific OAR is the reason for optimizing, PTV can have OAR cropped if normal tissue sparing is a priority



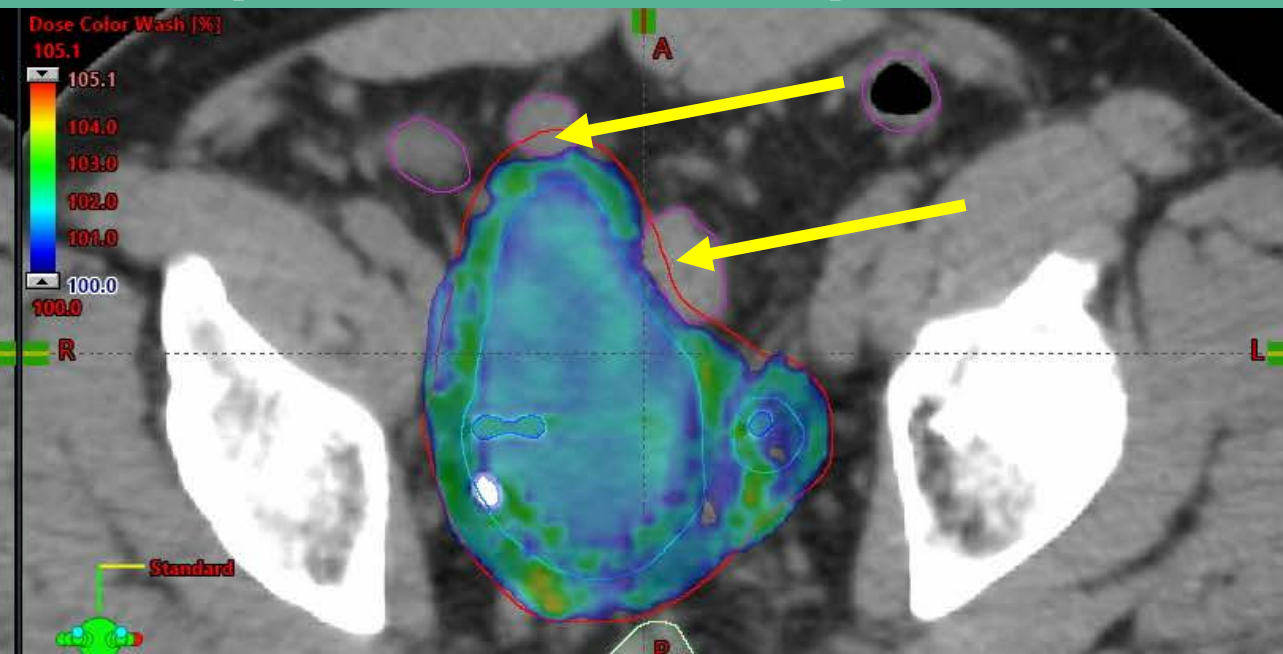
Adaptive Planning: Personalized Margins

- On daily adaptive plan, we have contoured the CTV of the day and the Bowel of the day so can optimize to a PTV-Bowel structure

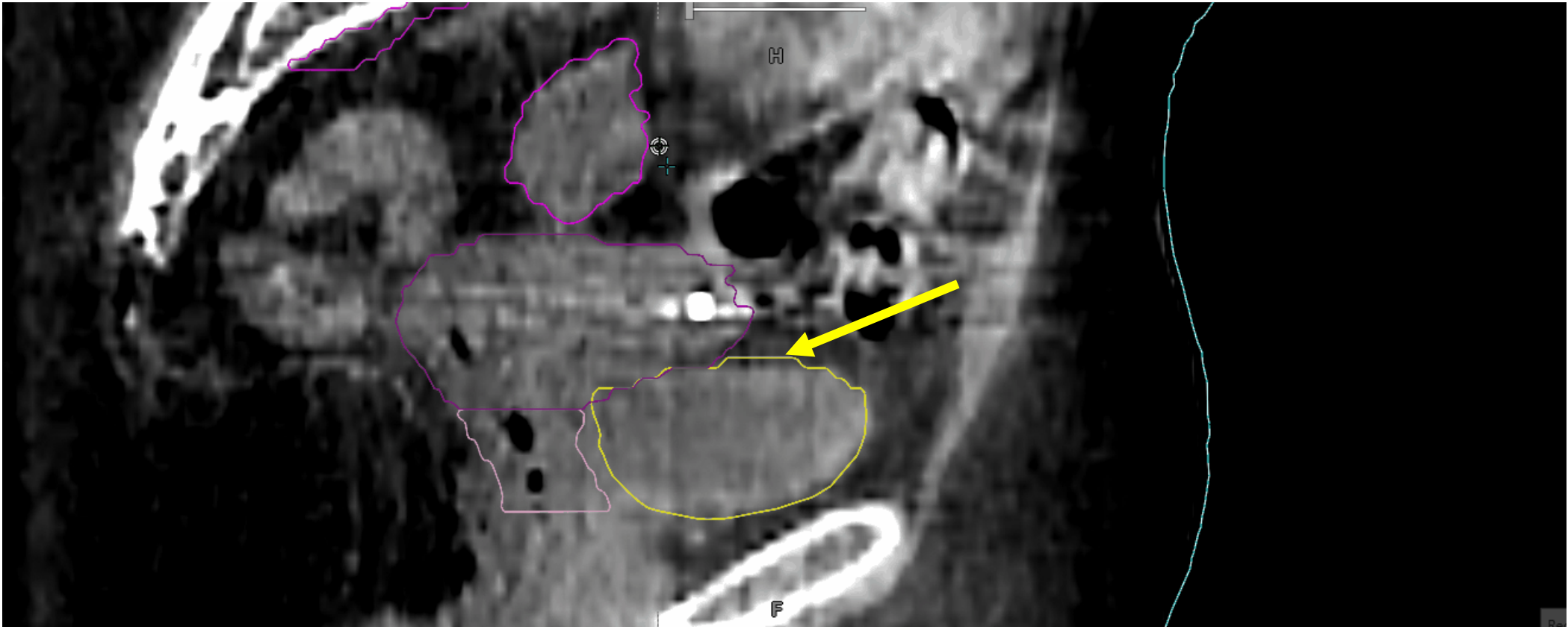
Standard Backup Plan



Representative Adaptive Plan

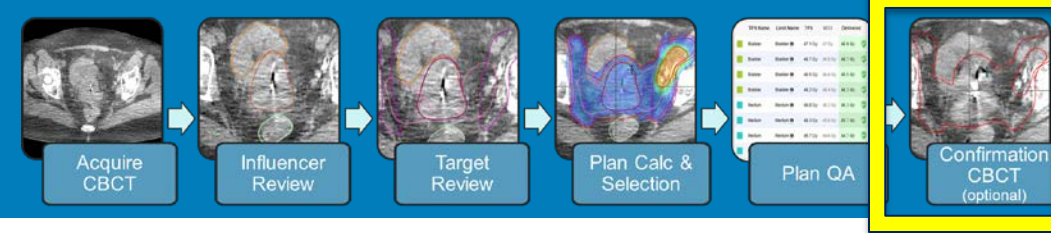


Personalized Asymmetric Margins based on Conf. CBCTs

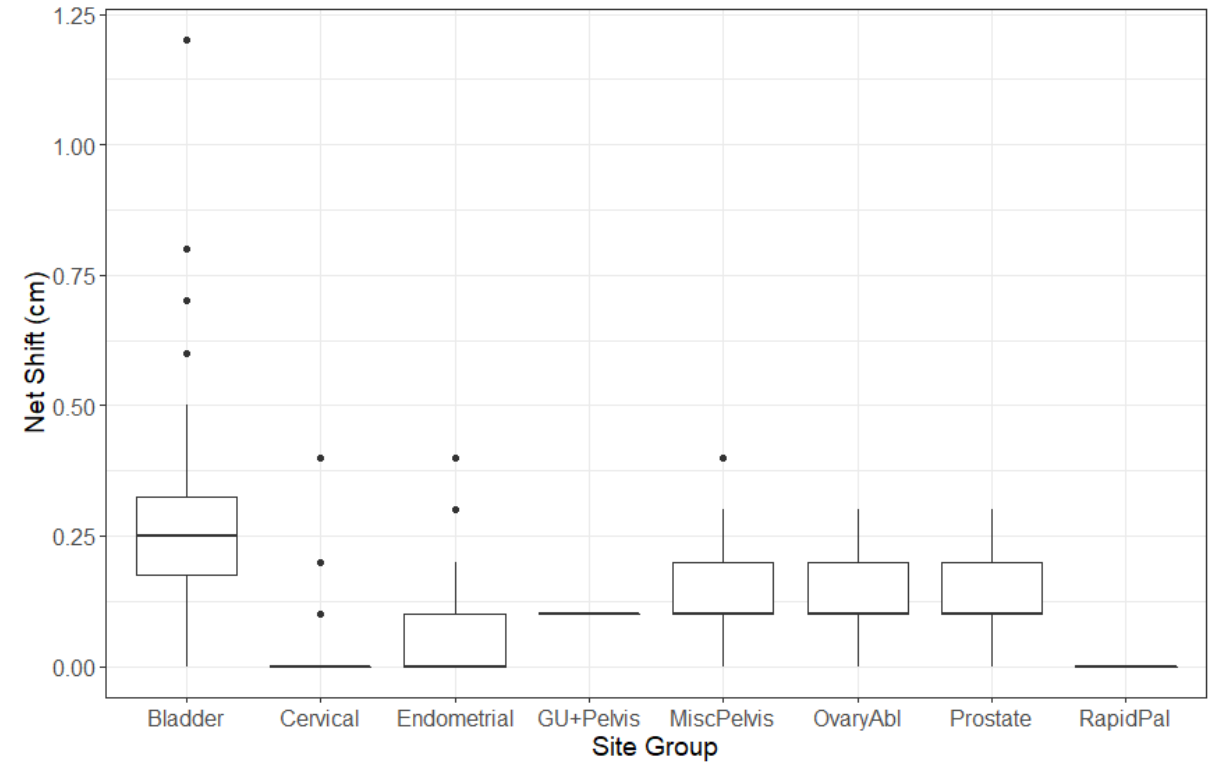
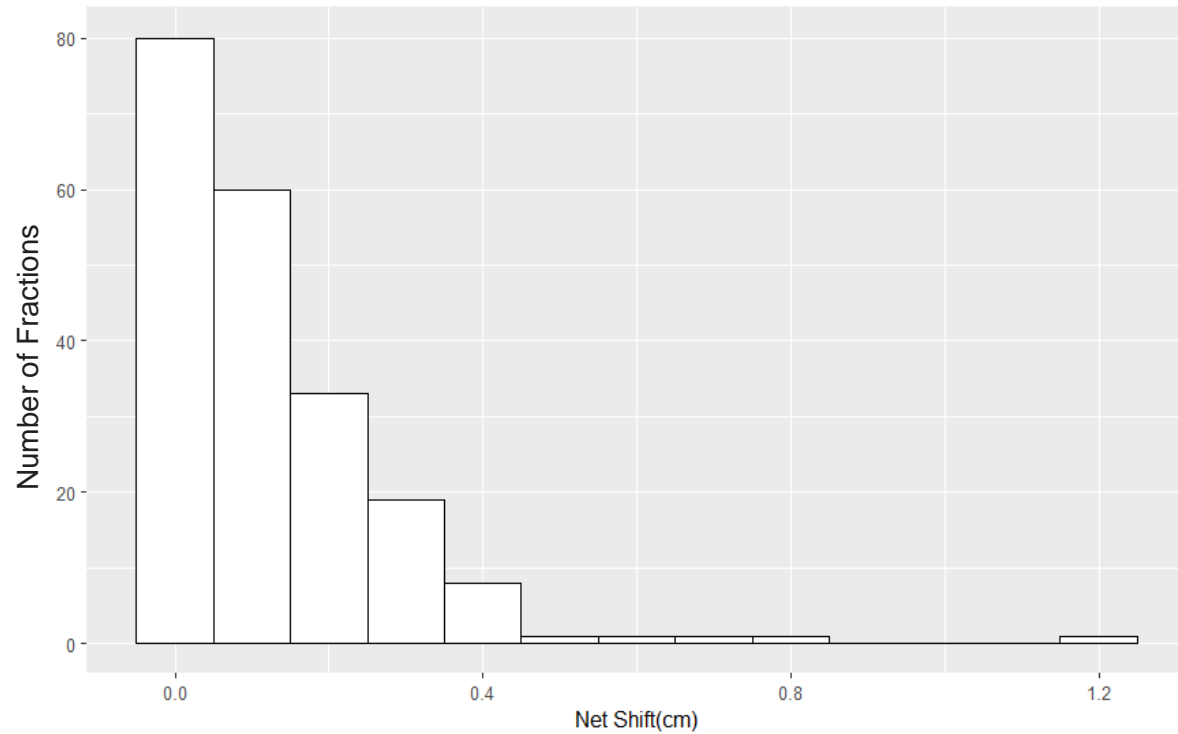


Can start patients with standard margins, and use first few fxs to evaluate intrafraction motion, and design patient-specific asymmetric margins

Conf. CBCT Shifts



Majority of shifts are <0.2 cm
Bladder patients had the largest shifts



Summary of our Experience

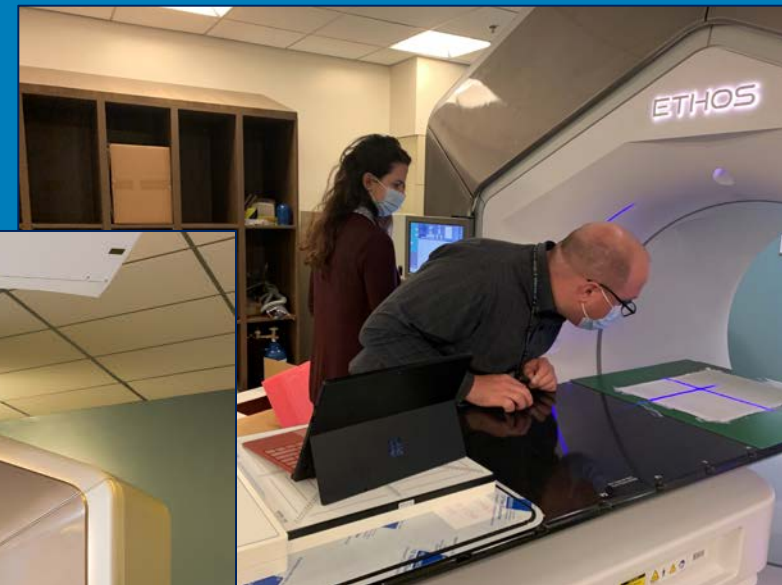
Successes

- Implemented daily adaption clinically
- Launched ARTIA-Cervix clinical trial to evaluate effect of ART
- Overall adaptive times are <20 mins
- Personalized selection of patients
- Personalized margins for adaptive patients

Ongoing Work

- More personalized planning: dose escalation or isototoxicity approaches
- Strategies to reduce the additional treatment time required
- Expanding to additional disease sites (pancreas SBRT, liver SBRT)
- Identifying poor ART candidates early
 - Visibility of target
 - Ability to lie still for 20+ minutes
 - Relative intrafraction motion

Thank you!



Contact Me: Xenia Ray,
xray@health.ucsd.edu